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TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

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INCORPORATED 1930

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Light and Colour in Daily Life

By J. W. STRANGE, Ph.D., A.R.C.Sc. *(Fellow)*, and H. HEWITT, A.M.I.E.E. *(Fellow)*

Summary

The paper makes a general review of lighting conditions to-day and points out the need for a greater diversity in lighting levels and brightness, in direction, and in colour. Much valuable information of an analytical nature has been revealed by academic studies made during recent years, but it is proposed that a parallel approach should be made along practical lines, guided by observation and imagination.

It is suggested that useful lessons can be learnt from the lighting techniques used in the theatre to produce visually interesting scenes, as these techniques can make an important contribution to experimental methods, particularly in providing variation of lighting levels and colour.

Some observations are made on the economics of artificial light, and it is shown that unduly large costs are involved in providing control over the distribution of light; such control could be simpler and less costly.

Finally, an examination is made of the reaction of the general public to the wider choice of light sources now available, and a plea is made for a more adventurous use of coloured light.

(1) Introduction

We are all users of artificial light, but we are not all equally observant of its effects. Some are concerned to use light only for utilitarian purposes, the more observant use light for pleasure, whilst others have also learnt to use it for profit.

The scope of artificial lighting is widening rapidly, and it may therefore be timely to ask ourselves what an observant person would think if he were to make a conscious effort to study artificial lighting as it exists today.

He looks out on a brighter world, sometimes a garishly glaring world. There have been great improvements in the standards of lighting which he observes during his working hours; this will be particularly apparent if he is a factory worker, as the great improvements in industrial lighting have probably not yet been matched in commercial lighting. If his children are fortunate enough to attend one of the more modern schools, they will enjoy good lighting conditions throughout the day; even if they are at one of the older schools, improvements have often been made or are on the way.

If our observer is impressionable, he will probably find that the most noticeable, and often the most attractive, changes in the use of light are those which are becoming common in commercial premises and premises devoted to entertainment.

In the observer's own home, however, he may find a very different story. If he is a handyman he has probably engaged in some home decoration, and has thought about lighting. He may even have made improvements, but in general there is much to be desired in the relighting of our homes.

Turning from interiors, where for many generations we have been able to dispel night, we see also that night is now rapidly on the retreat out-of-doors. Whilst much street lighting still remains to be done, the technique and standards now in vogue are acceptable to most people, and whilst they may occasionally complain about poor colour rendering and argue the relative merits of light sources, their chief complaint about street lighting is that there is not enough of it. Outdoor illuminations and floodlit sporting activities are becoming an accepted part of our nocturnal living, and may well make an important contribution to the fuller use of leisure.

Our observer may, therefore, be impressed with better lighting standards and with more extended uses of artificial light, but he may not be so impressed with the lamps,

The authors are with Thorn Electrical Industries Ltd. The manuscript of this paper was first received on January 23, 1956, and in final form on March 12, 1956. The paper was presented at the Society's Summer Meeting at Harrogate on May 9, 1956

fittings, and lighting devices employed. There is now a wider choice of light sources than ever before, but they have not all been readily accepted by the general public. In past generations artificial light has usually spelt warmth; nowadays it often brings a cold unsympathetic atmosphere.

These new light sources are not attractive in themselves, and no doubt our observer thinks longingly of the "life" of the fire and candle. He may have listened with interest to the homilies of the lighting engineer about the dire effects of glare, but he is now insisting on a degree of glare which he calls "sparkle"—which he likes.

It is perhaps unfortunate that light sources which tend to be cold, uniform and lifeless should have become available at a time when design of lighting fittings tends towards the bulky, the plain and the austere—or is this merely a case of "cause and effect"? The majority of fittings which are now available must be disappointing to those who like the ornate; there is apparently no contemporary ornateness.

If we consider the time element, this same uniformity seems to pursue us, for artificial lighting conditions do not often vary with time; when daylight is insufficient, our observer just switches on. He may even feel sorry that he *has* to switch on, as he is still quite convinced that artificial light is expensive.

(2) The Need for Diversity

It appears, therefore, that whilst we have been successful in the fight for reasonable illumination levels, we have in the process committed ourselves to lighting conditions which too often reveal an unvarying uniformity, and the general diagnosis of the lighting of our time reveals a need for diversity. After all, there is considerable diversity in the natural lighting conditions which are deeply ingrained in our visual experience. Consider the ordinary day from dawn to dusk—such as is easily simulated on a lighted stage. There is an amazing range of lighting conditions from the grey early morning light, through the rosy colours of dawn, the sharply directional light as the sun rises, the hard intensity of noon, followed by the softer light and the lengthening shadows of evening. To this sequence are added many variations, such as the grey dullness of overcast days and the sudden changes of storm. This is the general pattern of nature's light and it includes essential variations, not only in the colour and intensity of light, but in shadow and in the combination of general and directional lighting. In devising a practical approach to artificial lighting development, there is a great need for diversity if we are to get the right effect in the right place at the right time.

(2.1) Diversity in lighting levels

The promotion of new standards of lighting has tended to lay down so rigid a code that we are apt to forget that it may be effective if there is a variation in illumination level from place to place and even from time to time. To some extent this lesson has been learned in the rather tentative developments in domestic lighting during the last few years. Certainly, the use of local lighting has become fairly common, but too often the equipment used is acquired in a haphazard manner, and it is rarely part of a planned scheme. Nor is conscious thought often given to the difference in illumination level from room to room, though this often occurs by chance. As for control of illumination level from time to time, this necessity is apparently only recognised during television hours; and this only in domestic premises.

(2.2) Non-uniform luminance

The low brightness of the fluorescent tube has been of great value in providing high illumination levels without glare, but there is no doubt that this low brightness does not contribute to the design of attractive lighting fittings, though it may ensure

a narrow range of brightness ratios within an interior. Yet the narrow range of brightness ratios suggested by Logan[1] and other American workers will rarely contribute to lighting which gives positive pleasure. Further, our experience over the last few years has shown a demand for "liveliness" in lighting, and this presents a challenge to the designer of both fluorescent and tungsten filament fittings.

(2.3) Direction and diffusion

The development of large area sources and the trend towards lighter decorations has often resulted in the illumination of a room being omnidirectional. In display lighting this has already been shown to be quite ineffective, and the lessons learned in this field are now becoming relevant to the whole of interior lighting.

(2.4) Variety of colour

We have behind us many generations of incandescent lighting, which has resulted in a degree of colour distortion which has been constant through the years and has become quite acceptable by usage. The development of more modern light sources has produced a "choice of distortion," but as yet these sources have been received critically by the general public. This negative attitude, however, need not persist and the correct choice of light source for particular places and particular occasions could lead to a positive use of coloured light with exciting possibilities.

(3) Theory and Practice

Assuming that our diagnosis is reasonably correct, how do we move from diagnosis to a possible cure? During the last decade we have seen not only the exploitation of the newer light sources, but also a concern about the basic physical and mathematical factors on which the satisfactory lighting we all grope for would be based. This concern has resulted in a number of academic studies of great value and "The Design of the Visual Field"[2], together with its bibliography, demonstrates the scope of this work. Perhaps the value of these studies lies not so much in the possible development of a new and more intricate technique, but in provoking the lighting engineer to think more imaginatively about the practical work he is doing.

This is not to decry the theoretical studies, which must obviously continue, but we feel that a parallel approach along severely practical lines may be useful. This approach could be based upon the simple analysis which we have made and may derive its inspiration from our reactions, pleasurable or otherwise, to our natural environment.

Since this paper is concerned wholly with the practical approach, we find it necessary to state some obvious truths, if only to clear the ground. The visual field is controlled by three factors:—

(a) The objects and surfaces to be seen.

(b) The position or positions from which they are seen.

(c) The nature of the light falling upon the objects and surfaces.

So far as (a) is concerned, the practising lighting engineer has usually no control whatever, though he may be allowed to express an opinion on the decoration of surfaces. The position or positions from which the field is viewed may occasionally be fixed, as in a church, theatre or lecture room, but usually they are variable. The lighting engineer, therefore, may find himself only in control of (c) i.e., the lighting to be provided. He may like to control (a) (b) and (c) in order to achieve a completely satisfactory result, but this is possible only on rare occasions. These are the hard realities of the routine life of the lighting engineer, though we shall see later that there are also other difficulties, chiefly of a practical and economic nature.

If any justification were necessary for proceeding with a practical approach, it

can be found in the final paragraph of "The Design of the Visual Field" which reads:—

"Even if all the phenomena concerned could be so nicely defined, and if they could be exploited together without a serious clash of requirements, both of which suppositions are most unlikely—it is not to be supposed that a set of rules could ever be formulated, however well grounded, from which an outstanding design could emerge. In the final design architecture, furniture, decoration, colour and light will be compounded together into an æsthetically satisfying whole, and the design must result from combining the skills of the artist understanding technical means and materials and of the engineer appreciating the artistic aims. If some rules and limits emerge from the work here outlined, they must be used as clues to the artist-designer and as aids to the engineering of his design, rather than as regulations or codes compliance with which will secure a good result. There have been many attempts to shackle art with rules, but genius always breaks them; the art of designing the whole visual field is not likely to be an exception."

(4) The Lighting Installation—the Techniques and Basic Elements

(4.1) The lighted scene

It is intended to demonstrate on the stage some of the effects which can now be readily obtained, using simple combinations of lamps. The techniques which will be used are naturally, though perhaps not obviously, the techniques which are used for normal stage lighting. These are designed to give pleasure to the eye of the spectator, often by the simplest and cheapest means, and there is no reason why they should not fulfil the same purpose in domestic and other surroundings.

In the simplest terms, these techniques are concerned with three aspects of lighting: (1) Background, (2) General, (3) Accent. Each lighting engineer—or producer—will handle these in his own way, but in our view the logical order is as follows: The background can be dealt with separately, to give the right emphasis without being too obtrusive. This is particularly applicable in halls, passages or large rooms where it is possible to get sufficiently far away from walls for them to be treated as backgrounds.

The next in order to be dealt with is the accent lighting by directional spots and similar equipment. This has to be handled with care, otherwise hard contrast and disturbing shadows are produced. The general lighting is now provided, and this plays an important role in reducing the shadows without destroying the accent, and yet brings up the general level of lighting to the required standard.

This technique, developed in the first place for the stage, is now being used for shop window lighting and other display lighting, and in our view is equally applicable to interior lighting generally. Examples of the technique can be seen in, for example, dining rooms, where a decorative background may be a window covered by a venetian blind, lit from behind (Fig. 1). The accent lighting on the table is provided by local incandescent sources and the general lighting by concealed lamps in coves or beams.

While it is easy to demonstrate effects of this type on a lighted stage, the production of similar effects in small interiors raises all sorts of practical problems. To investigate this problem, it may be useful to consider the basic elements of the lighted scene separately.

(4.2) Working surfaces

Traditionally the main aim of illuminating engineering has been to provide a certain level of illumination "on the working plane." This plane has usually been a horizontal one, about 2 ft. 9 in. above floor level, and is sometimes a desk, sometimes a bench, sometimes a dining table, sometimes a counter, etc., etc. The science involved

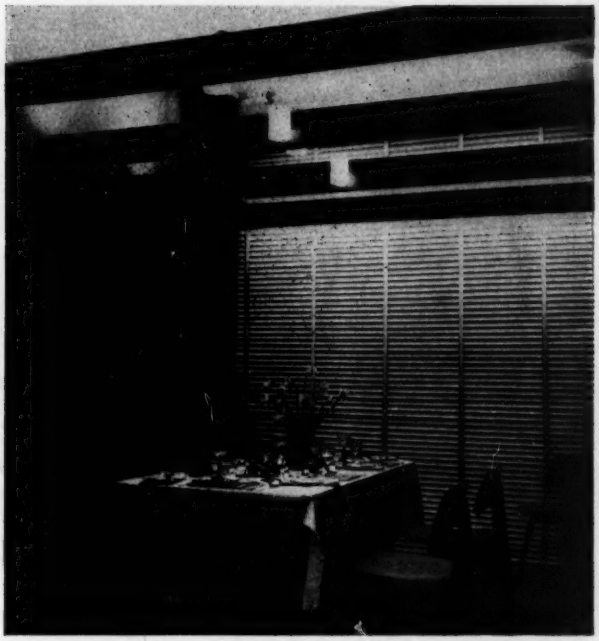

Fig. 1. Dining-room installation showing background, general and accent lighting.

in providing sufficient lumens per square foot on such surfaces has now been developed to such an extent that little need be said in amplification, except to call attention to the fact that opportunities for controlling brightness ratios are often neglected. Much has been said on the subject of brightness ratios during recent years, and we have already pointed out that often they involve considerations which are not in mind when lighting is being considered. When, therefore, the specific object of a lighting scheme is to light a bench top in industry, or a desk top in the office or school, then it is more feasible that some practical attention could be paid to colours and reflection factors, particularly as the sight lines are more or less fixed. The necessary action is primarily the responsibility of the user of light, but the lighting engineer could more often provide the spur.

(4.3) Walls

"The Design of the Visual Field" suggests that lighting can only be truly satisfactory if the eye can find "visual rest centres." Now in the majority of interiors we are concerned with sight lines at or just below the horizontal, whilst most "seeing tasks" are situated on one of the working surfaces referred to above. It would appear obvious, therefore, that visual rest centres (which are in any case likely to be large areas of low brightness) should be on the walls of the room, yet in recent years we have been so determined to depart from the central ceiling point that we have seen an outcrop of wall brackets, some of which, though well designed, are of quite high brightness. Perhaps we have gone too far in creating a fashion in this type of lighting.

The "pelmet" idea, especially when associated with the fluorescent tube, is a very promising lighting instrument, as it can be used not only to provide effective lighting of the vertical surfaces, but also to distribute useful lumens by reflection from the ceiling (Fig. 2). In addition, the face of the pelmet gives scope for decoration

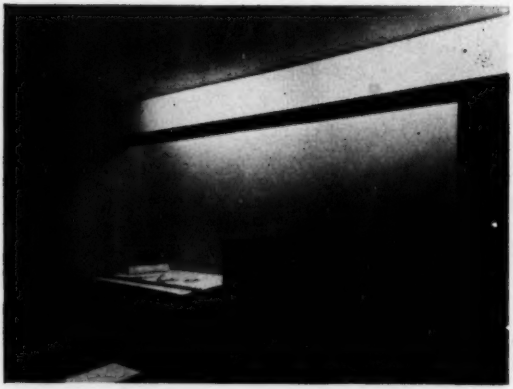

Fig. 2. The 'pelmet' principle applied to office lighting, given an illumination of 50 lm/ft² on the drawing-board and assisting also the general lighting of the office.

and if the pelmet board is pierced with small holes, sparkle can be provided, even from the fluorescent tube. Pelmet lighting has so far been used in possibly the worst way, i.e., in the lighting of curtains—for it can be shown that draped fabrics are only really effective when lighted from the side, so that the folds are emphasised by light and shade.

When fluorescent lighting had become firmly established, the suggestion was made that artificial windows be used as lighting features. Since then it has become apparent that there is no technical problem involved in doing this, but we have also learned that the severity of glare depends not only on the brightness of the source, but also on its area and its orientation in relation to the eye. The last two factors would seem to preclude an artificial window from most interiors unless there could be some control of its brightness. This could be achieved quite simply by the use of the venetian blind as shown in the photograph of the office installation (Fig. 3).

In this installation white fluorescent tubes were used and produced a satisfying

Fig. 3. An artificial window used for office lighting.

result for office lighting In other situations the same device would obviously call for lighting of a different colour, and it is not too fanciful to suggest that this colour should be changed from time to time by easy manual control. The colour-blend circuit, which provides preferential dimming of pairs of tubes or groups of tubes, can be shown to provide an easy and economical means of colour-change lighting which can be very effective when applied to the artificial window.

In the treatment of wall surfaces the question of colour is, of course, of great importance and must be a vital factor in the provision of visual rest centres. Structural difficulties must be overcome in order to achieve good results, but it will be shown that it is possible to light a wall effectively not only from a "pelmet," but also from a ceiling and even from another wall. Further, all these methods lend themselves to colour-change lighting if this is desired.

(4·4) Ceilings

By the nature of things the ceiling is likely always to be the most important structural element in artificial lighting. Illuminating engineers have long advocated the provision of light ceilings in order to avoid undue brightness contrasts and also to dispel "tunnel" effect. It may be asked whether we have gone too far in this direction. The tunnel effect produced by cut-off street lighting is generally thought to be a disadvantage, and yet it would probably be agreed by most people that it serves to concentrate the attention. This can be more dramatically illustrated when one considers visual conditions on a floodlit football ground, where a maximum illumination level of 20 lm/ft^2 provides for many people a greater sense of visual acuity than, say, the 500 lm/ft^2 in which the game might be played on a winter afternoon.

If, therefore, it is desirable either to concentrate the attention for working purposes or to create an intimate atmosphere in which the sense of one's surroundings should be kept to a minimum, then possibly there may be some justification for a relatively dark ceiling. One move in this direction has been the recent technique of lighting a

Fig. 4. The main concourse at London Airport showing the interesting ceiling structure which provides indirect lighting.

dining table by means of light sources situated only 3 ft. or so above the table, and using opaque reflectors.

When, however, the ceiling is employed as a secondary source of light, in indirect or semi-direct lighting, it has generally been assumed that it should have a plain white matt surface, yet if the surface were broken in an artistic fashion by means of mouldings, etc., a pleasing effect could be obtained without materially reducing the efficiency of the ceiling as a reflector (Fig. 4).

Once again, however, it is in the use of colour that we see the possibility of experimental work that may lead to fruitful results. Let us consider three well accepted ideas:—

Firstly, it is not often possible to achieve satisfactory lighting without some upward component of light.

Secondly, electric light is cheap, and the total efficiency of a lighting fitting or lighting device is not perhaps so important as we are apt to think.

Thirdly, there is now a great demand for more colour in interior design.

These three factors lead to the suggestion that deliberate attempts should be made to provide an upward component of light which is of different colour from the downward and more utilitarian component. Whilst the main application of this idea would be in suspended fittings, it is possible also to apply the idea to the pelmet device referred to previously. If, for instance, two tubes were used behind a pelmet, the upper tube could provide coloured light for the upper portion of the wall, spreading also across the ceiling.

The logical extension of this idea would be a suspended fluorescent fitting employing tubes of a different colour (Fig. 5). The downward component of light would be near-white, whilst the upward component would be coloured to suit the decoration of the room, the function of the room, the occasion, or the season of the year. For the larger interiors which could accommodate bulkier fittings, colour-change lighting could be provided on the colour-blend system so that the appearance of the room could be changed with the time of day, from mood to mood, or from event to event.

The nearest approach to this idea which has yet been adopted in this country has been colour-change lighting from a cornice. This has proved quite successful, but the time has come to be a little more adventurous in the use of coloured light.

In recent years there has been a tendency to use small areas of unsaturated colours on the ceiling, and this can create a satisfying effect without making any real alteration in the overall colour of the lighting. This thinking can be carried a stage further to the development of lighting fittings whose upper translucent panels are coloured, thus creating an interesting coloured pattern on the ceiling, and yet giving an efficient downward distribution of near-white light.

The ceiling structure can also be used to house light sources required for accent

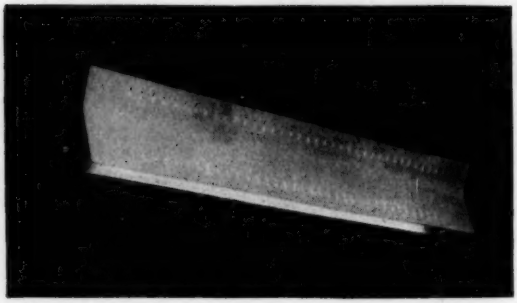

Fig. 5. Fluorescent fitting to provide upward and downward components of light.

Fig. 6. Corridor lighting using the "baffle" principle.

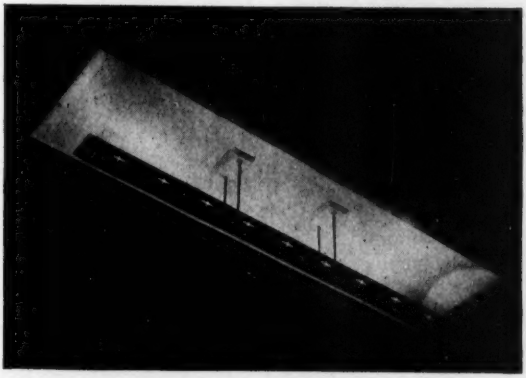

Fig. 7. Fluorescent fitting designed to combine sparkle with indirect lighting.

lighting or for directional and colour-change effects. This is probably best done from behind baffles, which also lend themselves to treatment with unsaturated colours (Fig. 6).

Finally, if sparkle is necessary, what better place than the ceiling to provide it? Most people like a starry sky, and if small spots of brightness can appear in lighting fittings they can only contribute "life" to the lighted scene. Even the fluorescent tube can be used to this end, as is shown in the photograph of the special fitting designed

with a pierced opaque reflector. This fitting demonstrates how built-in lighting can provide good illumination which is lively without being glaring (Fig. 7).

(5) Limiting Factors

The foregoing pleads for a more liberal use of light and greater flexibility in its control, and since new light sources and their equipment are now available, and since the theoretical ground has been fully explored, what are the factors which still prevent experimental work of an imaginative nature? Important factors are economics and structural and supply difficulties.

(5.1) Economics

Artificial light is cheap. It can be proved beyond doubt that the benefits obtained from it are out of all proportion to its cost, but many people are still influenced by the reactions of earlier days when electric light, in particular, was considered to be a luxury. The newer light sources are much more efficient than the old, but pride in this achievement has tended to obscure the fact that efficiency is not everything, and that with the relatively low cost of electricity for lighting it may well be that the current consumed is not of great importance, particularly in the home. This lesson needs bringing home to the general public. Further, with the improvement in illumination levels has come an increasing dissatisfaction with daylight conditions; this means that the use of artificial light is justified during long periods of what is generally thought to be "daylight" and this is not the extravagance that many people think.

Although artificial light is cheap in itself, the means for controlling this light are becoming more expensive, mainly because of increased size of fittings, greater complications of circuitry and sometimes the use of more expensive materials. There are signs of a new development which might help to reverse this trend. The introduction of the reflector fluorescent tube shows the possibility of in-built control of light distribution without any major increase in cost. The application of a similar technique to incandescent lamps has given a range of simple products which provide a valuable measure of light control.

As far as domestic lighting is concerned, it is possible that we expect our lighting fittings to last too long and it has been pleasing to find a noticeable trend towards the use of expendable materials; the day may yet come when our lighting ideas are changed as often as our ideas on decoration.

(5.2) Structural and supply difficulties

The development of new lighting ideas is also retarded to a great extent by the scarcity of socket outlets, the cost of installation work, and the difficulty involved in making structural provision for built-in lighting. If the lighting engineer is puzzled to know why more use is not made of his new ideas and new light sources, the answer is probably manifest in his own home, for if he considers doing any alteration to his lighting other than the most conventional, he is immediately faced by installation and structural difficulties.

Many rooms depend for lighting upon one central ceiling point—that rigid survivor of the gas era—though in some cases a socket outlet is also available. In the case of new houses the architect can help, although he often finds that he is too strictly bound by cost, and the small amount available for lighting is likely to provide the same central ceiling point and one socket outlet.

If this position is to be improved there must be co-operative effort between the architect, the builder, the electrical contractor and the lighting engineer, as well as the occupant of the house. The greater use of ring mains would give more flexibility, but the situation would be further improved by the development of special equipment lending itself to many applications. This equipment might include, for example,

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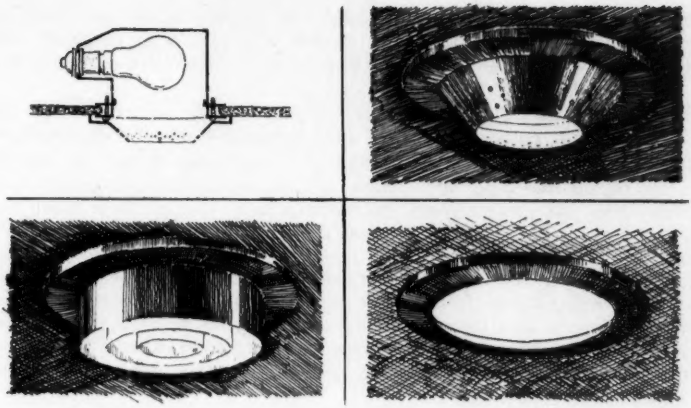

Fig. 8. Variations on a shallow recessed fitting designed for an incandescent lamp operating horizontally.

plaster-depth trunking for use behind skirting boards, combined trunking and picture rail for surface mounting, and combined trunking and cove lighting fitting.

So far as lighting equipment is concerned, the developments towards built-in fluorescent lighting have not been matched by the provision of built-in tungsten fittings suitable for use in the home, and there is a demand for recessed or semi-recessed fittings suitable for use with 7-in. joists, and incorporating lamps which can be operated horizontally. The use of wide rims to these fittings to hide jagged holes in plaster would, in the experience of the authors, be an advantage (Fig. 8).

(5.3) Colour—its acceptability and specification

Another considerable factor, limiting experiment and development, is the reluctance on the part of the public to be more adventurous in the use of new light sources. Even here there has been some change in outlook in recent years, for the average user of light will accept colour distortion when it cannot easily be avoided (e.g. in street lighting) and he may yet find that what he now calls colour distortion may sometimes be quite acceptable. It is the subtler points of colour rendering which cause most of the trouble.

The ordinary person still finds colour properties difficult to appreciate, in particular the difference between colour appearance, or chromaticity, and the spectral distribution of the light or its colour rendering properties. The effect can be demonstrated, in an exaggerated form, by illuminating white and coloured objects by two light sources which both give light of the same colour but have very different spectral distributions. In a less exaggerated form this effect is responsible for all the colour-rendering problems under artificial light. These problems can be grouped in four main categories.

(1) The critical colour requirements of the dyer, the colour printer and other experts who are concerned with matching colours. This field is a specialised one which is outside the scope of this paper.

(2) The conditions in everyday living, where a measure of good colour rendering is essential for acceptability. This is a most important problem and applies particularly to the assessment of the colour of food, clothing, soft furnishings, and complexions.

(3) In the wide range of general conditions, whether in factory, office or home, we are in practice remarkably tolerant of a very wide range of colour and colour rendering and, in fact, this range is often advantageous by adding variety and interest.

(4) There are also a number of conditions, already referred to, of deliberate distortion of colour, which are quite acceptable for limited conditions.

Although we have decided to exclude the first category and we can naturally exclude the fourth, the other two, where we are concerned with general conditions of everyday life, still present some difficult problems, one of them being that what people in general prefer as "good" colour rendering is not necessarily correct colour rendering.

This is shown by the work of Sanders, reported on at the C.I.E. meeting at Zurich.[3] As will be seen from Fig. 9, which is taken from that paper, we sometimes tolerate quite a wide range of colour rendering for familiar objects like potato chips and beef steak, although at other times we are very critical as with butter and tea, but sometimes we also prefer them to be quite different from their normal appearance under daylight.

The fluorescent tube is responsible for many colour rendering problems, because of the unusual combination of line spectra and band spectra and also because efficiency and colour rendering quality make opposing demands. For example, high-fidelity tubes like Natural and de Luxe Warm White are about 20 per cent. less efficient than their high-efficiency counterparts, Daylight and Warm White. Attempts of varying complexity have been made to define the differences, mainly for purposes of specification;[4] many of them are so involved as to be quite meaningless in everyday terms. Others are based upon conditions such as those of simultaneous comparison, which are rarely met in daily life and are far more critical than our normal viewing conditions. One of the most interesting attempts was that made by Crawford.[5] He illuminated a small test picture by light derived from a specially designed spectroscope. By dispersing the light into a spectrum, then eliminating certain wavelength regions and then recombining it, he was able to illuminate his object with light from which varying amounts of different bands had been subtracted. His test procedure was to ask an observer to report when the colour rendering of the picture under observation had changed to the point where it was noticeable. In this way

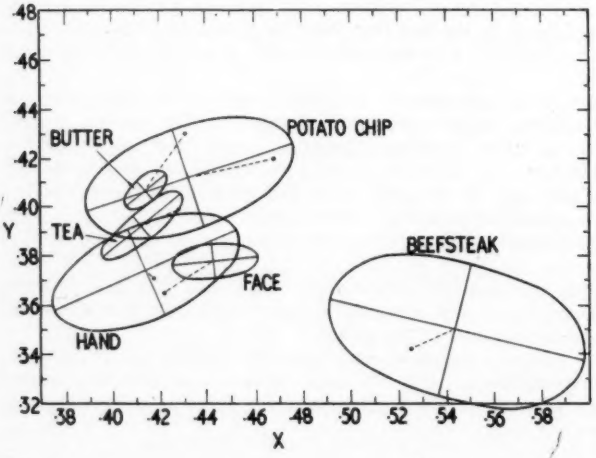

Fig. 9. Tolerances for fair colour rendering and chromaticities of typical samples under Source B. (Sanders—C.I.E. 1955).

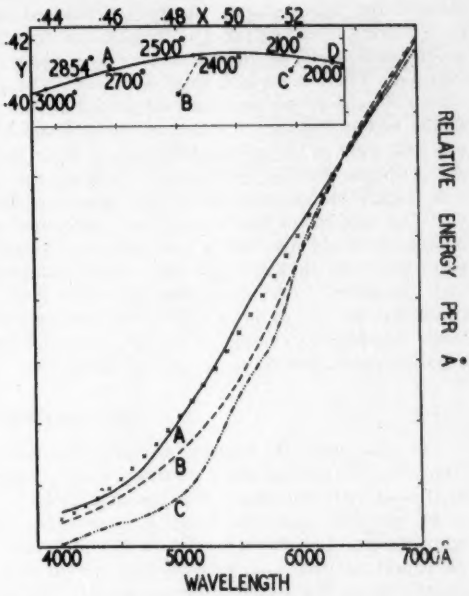

Fig. 10. Spectral energy distribution and chromaticities of various sources :—
(A) White incandescent lamp
(B) Pink tinted incandescent lamp
(C) Flame incandescent lamp
(D) Candlelight

he was able to assess the amount that could be removed in different spectral regions without any apparent change in colour rendering.

The conditions Crawford used were necessarily rather artificial, because his observers were looking at a relatively small patch, were not under normal conditions of viewing and were presumably not fully adapted to the illumination under consideration. In any case, such an experiment does not lend itself to large scale use. We have repeated the same experiment in a small room, using fluorescent lamps and filters giving a much less exact separation of the bands, but with the obvious advantage that the whole room can be illuminated and the subject be fully adapted to the illuminant. The results of these experiments are given in Appendix I.

To elaborate further on such laboratory experiments would get us too far from the practical problems. One such problem is the choice of the correct colour of lamps. This usually arises with the fluorescent tube, which by its nature permits a wide range of choice. The final preference for most purposes seems to lie among colours equivalent to black body temperatures from 3,000-4,500 deg. K, i.e. from a colour fairly close to that of the tungsten filament lamp to something nearer to daylight. The weight of tradition is undoubtedly behind this choice, but there is strong evidence for a preference for something somewhat pinker for domestic surroundings and lower levels of illumination.

We have investigated, in some detail, the reactions of users to comparatively slight alterations in the colour of the incandescent lamp, made possible by the addition of small quantities of pigment to the internal silica coating used in the "White" incandescent lamp. The changes in colour and in the spectral distribution curve are relatively small, as will be seen from Fig. 10, but it was clearly shown by the reactions of those who used the lamps that quite small changes as shown by point B in Fig. 10 were perceptible in such things as complexions and food, and were preferred for many purposes.

The general impression was, however, that when the colour was altered as far as

point C the light became perceptibly coloured and unacceptable for general illumination. One interesting point is that this is close to the colour of candlelight which, at much lower levels of illumination, is once again not only acceptable but highly recommended. There is no easy single solution. The greater use of the "de luxe" or "high fidelity" lamp is one practical but partial answer. Another partial answer is contained in the recent comment of one of our colleagues that "at high levels of illumination you lose sight of the colour distortion." With the trend towards these higher standards and with the growing experience of the general public in the choice of light sources, it is hoped that unfortunate colour-rendering effects will become rarer.

This section, of course, has been concerned with a fairly close range of what may be described as "near-white" sources, and within this range the lighting industry must be prepared to meet criticism with patient educational work before our "colour problem" is solved. We must, however, refer back to what was said in earlier sections about the use of coloured light—even strongly coloured light—in building interesting visual conditions. Though this light may not reach "the working plane," it can be a positive contribution to the act of seeing.

(6) Conclusions

In past years the lighting engineer has been intent on providing a lighting level rather than a lighted scene, and has largely ignored the lessons of his own environment. Recent academic work has stimulated a more detailed practical examination of the problem, and this shows a present-day need for a greater variety in artificial light—variety in lighting levels, variety in brightness, variety in colour, and the lighting conditions that change with time, mood and occasion. Examples of this variety are shown in two widely different realms, the realm of nature itself and that of the theatre, where artificial lighting devices are deliberately employed to create a scene that is interesting and pleasurable.

But the lessons we learn from our observations must be carried into practice, and this demands an easier physical control of artificial light. First, there is the control of light distribution, and this calls for simpler and less expensive lighting fittings and lighting devices. Secondly, there is a need for a wider control in the colour of artificial light, demanding a more adventurous use of the colour sources now available, the application of colour-changing techniques, and a sustained effort to educate the public to the positive pleasure that lighting can give.

The authors thank the directors of Thorn Electrical Industries Ltd. for permission to present this paper.

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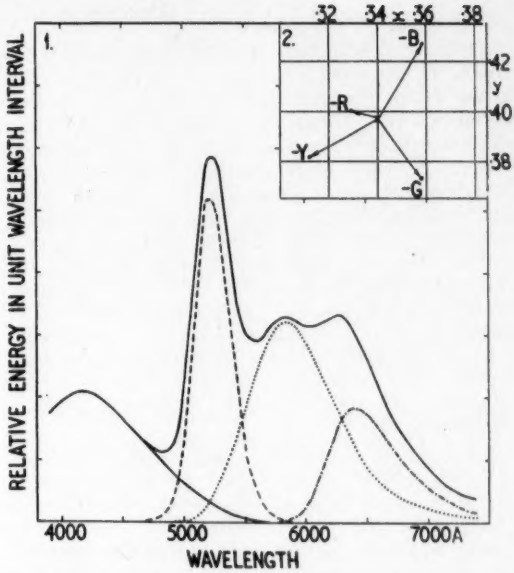
Appendix

Experiments on Colour Rendering

It was only possible to achieve the large scale experimental conditions successfully by limiting the spectral bands under consideration to four, and also by allowing much greater overlap of the bands. Details of the distribution of the four sources are given in the diagram (in which, for clarity, mercury lines are omitted). The experimental arrangement was for the observer to sit about eight feet away from the subject who



was dressed usually in some dark fabric with a fairly dark background. The main objects in the field of view on which changes would be apparent were therefore hands, faces and in some cases coloured fabrics. The experiments are still in the early stages. The main feature so far investigated has been the effect of the level of illumination on the observations. Experiments were made at illumination levels of 5 and 75 lm/ft^2. The lower level was close to the higher level used by Crawford.

The observers were asked to report when there was a noticeable difference in the appearance of the subject, as one colour band was slowly decreased. This might be, according to the conditions of the experiments, a difference either in chromaticity or in colour rendering. The chromaticity changes were quite large as will be seen from the colour co-ordinates given in the diagram. Intensity changes were sometimes apparent before any apparent colour change. Each band was taken separately in a random order with two "dummy" runs for check purposes. Average times before change was noticed were about two minutes. The results at 75 lm/ft^2 for the four observers are given in the table, and the average figures are compared with the average figures at 5 lm/ft^2.

Percentage removed before change noticeable.

Luminance	Observer	Red	Yellow	Green	Blue
75 lm/ft.^{2}	A	51	34	52	16
	B	29	35	18	19
	C	48	30	39	44
	D	53	42	47	50
	Average	45	35	39	32
5 lm/ft.^{2}	Average	46	38	37	38

The results agree fairly closely with the tolerance of about half a band reported by Crawford and give no support to the assumption that over this range intensity makes any difference to the apparent effect.

Discussion

MR. J. M. WALDRAM: I am most grateful for the opportunity of opening the discussion on this paper, for I appreciated particularly the authors' reference to the report on the design of the visual field which was produced by a committee with which I was associated. The paper is a proof that that report succeeded in its main object, which was to get the designer thinking along the line which the authors have taken to-day: not where he can hang up a light, or whether he shall use direct, semi-direct or indirect, or any other system, but what his interior is going to look like. If you start thinking along that line, you will very quickly get results, and there are many devices of calculation to help you which can be employed in any detail that the job justifies. We have recently had further proof of the detailed methods of calculation which enable one to start with a proposed appearance and to work out which equipment to use and where to put it and to obtain as a result the appearance which was specified. It is occasionally necessary to do this in some detail, and it is satisfying to know that, where we want it, we have got the tools; though the most elaborate tools are not always necessary. If we start by thinking what we want to get by way of designed appearance, a man of reasonable ingenuity can get it without going into unnecessary detail.

The authors quoted from the report a statement that rules can never be formulated by which a first-rate installation will be produced. That is obviously true, because we are dealing with an artistic matter. Nevertheless, there has been a good deal of thought since that report appeared, and one point of some interest was brought out in a paper at Zurich that the lighting problem is exactly parallel to a lot of other problems the architect has to face. An architect has to work always within a framework of rules, codes, requirements and legislation, and within that framework he has to design something which shall be an artistic success. I believe I am right in saying that the Gold Medal for architecture is not awarded to the man who has most conscientiously obeyed all the rules, codes and specifications, but to the man who, within those rules, manages to design a work of art.

It is the engineer who sets the rules because the engineer does the measurement; all he can measure is when something breaks or fails, so he sets rules to ensure that the building will stand up and be habitable; and then it is up to the architect or artistic designer, within those rules, to produce the success. Exactly the same thing happens in lighting; the engineer measures what it is wise not to do and produces codes to tell us not to do it. Within the limitations of those codes, it is then up to the artistic designer. The case is exactly parallel with all the other features of the building and the services in it.

I am absolutely with the authors in their insistence that we need diversity, and I am against those who say we should have everything down to a nearly uniform brightness. We need accent, we need places to look at, and we need visual rest centres, and you cannot accent something if you try to accent everything. If we are going to accent some places, others must be subdued, but the design of the pattern of brightness is important. I think the proposals for a three-to-one limit in brightness above and below the mean brightness is an example of a rule which is not well-founded. We should see whether we can safely break it, bearing in mind, of course, the reason for which it was originally made.

We have seen much on the stage to-day about the effects of direction, a subject on which we have a great deal to learn. One thing which we found in our work was the importance of the direction of modelling. Modelling from the top is usually considered not to be modelling at all. Most people when they talk about modelling really mean modelling from the side. Reference has been made to problems of church lighting. I may mention the effective use which can be made of a very gentle

spotlight from one side, to give a discreet degree of light on the preacher in the pulpit. There may be no very obvious effect, but if the spotlight is switched off the preacher looks like a Negro and you cannot see his face at all. The modelling does not cause glare, it lifts the brightness and gives the necessary modelling to make the preacher in the pulpit look natural and has a most beneficial effect. One ecclesiastic said to me: "I do not want anything theatrical, but I want a dramatic effect," in which, of course, he was perfectly right; the theatrical is the dramatic which has been found out.

The authors pointed out the advantages of having ceilings not so bright as they often are. A survey of the brightness of ceilings by artificial light and daylight shows that in most installations at night the ceilings are very much brighter than they are relatively by day. There is a lesson to be learned there, though we do not want to ape daylight. We do not want to make our ceilings so bright that they steal the show. One of my observers, looking at a photograph of a well-known building, lighted indirectly with a very bright ceiling, said: "It looks rather like an aquarium." The light seemed to be filtering down from above, and one looked like a fish in a tank. The amount of upward light which is needed is often zero, for the ceiling receives enough light by reflection from the floor.

I sometimes wonder how far we should go in the provision of pink lights; whether we are wise in putting colour into the light, or whether we should do better to provide white light and put the colour into decoration. If you put pink lights in a restaurant everything goes pink, including the tablecloth, and the china, users adapt to it and their white point moves to the pink; objects which should look red seem paler. In some restaurants, however, the decoration is in a very pale blue and the light is white; then the white point goes a little into the blue and all the warm tones of the meat look warmer and more succulent and attractive and the polished wood looks better coloured. In these ways we can bring the accent of the colour to the places where we want it, whereas if we flood the whole place with colour we lose the accent in the one place where we want it. This may contradict some of the things the authors have said, and I wonder if they will give us their views.

MR. H. E. BELLCHAMBERS: As one might expect, Mr. Waldram having been asked to open this discussion, there is very little anyone else can say. We all know he is very much an expert on these problems and has done a considerable amount of research work in which we are all very interested; a number of points which I hoped to raise have been covered by Mr. Waldram.

I think that the plea for diversity in both colour and character of lighting is very worth while, but I think that the effects which we see on the stage and in display are often exaggerated, for obvious reasons, and if we introduced such effects into the home they would have to be in a very moderate tone. The effects on the stage are very closely related to grease-paint, and I should hate to think that our wives, and children perhaps, thought it necessary to put on grease-paint to match the lighting scene.

To get down to one or two technical points in which I was interested: particularly, the authors' reference to the acceptability of colour rendering and appearance. For various purposes, they showed some very interesting examples of colour appearance and colour-rendering effects, and they drew attention in the written paper to the work of Sanders, who has shown the tolerances which have been found acceptable by his group of observers when observing common objects like beefsteak, chips, and so on. I think there are several points here worth remembering: the eye does adapt to the general overall colour appearance of the scene, and it does, given time, accept some distortion and makes some adjustment for distortion in colour rendering. In the demonstration we saw earlier on the stage, when the colour content was being changed very slowly, the difference in colour rendering was hardly perceptible, but when it was done rather more quickly, the colour-rendering changes were easily seen.

Another point is that, notably, artists and architects are rather hypercritical about

colour rendering. One recent example I came up against was the artist who objected to ordinary picture glass because of the distortion it brought to the colour of his paints; and we do have to take into account, in lighting design, what artists and architects think about these things. So I think it is important not to allow ourselves to be over-excited about the possibilities of colour, because of the distortion which might be introduced.

My experience of a large number of subjective assessments of colour rendering and appearance, in which we have used observers, some of whom could be called experts, others non-experts, where we have, over a period of the last five or six years, done a number of experiments using up to 50 observers in each case, is that when presented with a choice of sources of varying colour rendering and colour appearance, observers do generally agree fairly well with one another. There is the odd individual who objects violently to what the majority think is the best colour rendering, but on the whole there is a fairly good general agreement on what is good colour rendering. One other important thing we discovered—at least, we think we discovered —was that where observers are presented with a choice of sources of slightly different colour-rendering properties, the basis on which they make the final choice is that of colour appearance. I think that all these points should be carefully borne in mind if we do introduce colour into the home, or anywhere, in the fashion which has been suggested by the authors.

One or two practical points which came out of the demonstration : I noticed that, at one time, the legs of the chair were green, and a few moments later they were red, and then they turned to a purplish colour. The upholstery on the seat also changed. It was probably not intended, in the home or anywhere, to make the changes as rapidly as we saw them this morning; nevertheless, I think if you did introduce anything like that into the home, it might be very well to use it at Christmas time, but after a while you would want to throw it out.

MR. C. J. KING : It appears to be one purpose of this paper this morning to stimulate an interest in new ways of lighting homes, and although, as I think has been said, we get more opportunity of lighting old homes than new ones, an experience of mine, which is a very personal one, rather shows the difficulties we are up against.

A certain fairly large housing estate in Scotland is being built by a builder who is not really speculative, as the houses are built after they are sold : he is allowing 1 per cent. of the selling price of each house for the electrical installation. That means, the cheapest houses there being £2,500, he allows £25 for the electrical installations. Very few of the people who buy these houses have any knowledge as to what can be done about the lighting, or about other uses of electricity. The result is that they go into these houses with this " one per cent." installation and they have to do the alterations at very considerable cost afterwards. I think only propaganda can help, and this paper may do a little towards it.

The second item is more in the nature of a request than a question. The lamp makers in general seem to be falling over themselves to provide lamps of definite use, but very limited use. The reflector-lined fluorescent lamp is an example I have in mind. Could we not have a fluorescent lamp for use in existing pelmet installations which has two colours, one half, shall we say, a nice pink, and the other half a daylight blue ?

MR. J. G. CHRISTOPHER : On looking back over the years, it seems to me we have now reached the stage where we can talk about the complete emancipation of the lighting engineer. There have been three " freedoms " : I think the first freedom was, as the late Sir Clifford Paterson said, the freedom of electricity from its wires when the discharge lamp was introduced. The second freedom, for which we must thank Mr.

J. M. Waldram to a very great extent, is the freedom from the lumen per square foot in favour of the visual field; and the third freedom is the freedom from the colour of light that we have been using for most purposes for so long.

There has been a temporary eclipse of colour for, I should think, 15 to 20 years. There was far more colour used for lighting 25 years ago than there was four or five years ago, and I think the focus we have had to-day on the use of colour is something which is very important. Probably, the introduction of the fluorescent lamp was responsible to some extent for that eclipse because, certainly in the earlier days of the fluorescent lamp, it was not easy to obtain the colour or the control over the colour that we have to-day.

I think the pink-tinted tungsten-filament lamp has its attractions in spite of Mr. Waldram's point of view about obtaining colour through the decorations. The attraction of the pink lamp is that, if the colour is well chosen, it does produce a rather less yellow-green tint than the old tungsten lamp we have become so used to. In other words, it should not really be regarded as a coloured lamp—it is a corrected-white lamp, and it does not give an impression of colour at all, except that it rather improves the colour rendering for social purposes.

One thing I think we must watch is that, if we use colour, it has got to be done very cleverly to escape some of the crudities that are possible. I think in a well-decorated interior badly applied colour can look garish and unpleasing, and it is something that must be controlled very carefully to preserve the dignities of the interiors we are concerned with.

MR. F. JACKSON: I have no axe to grind concerning colour diversity but I am a lampmaker, pure and simple. I am interested in the way in which colour diversity will be achieved. The authors have mentioned the importance of cost, and I hope that they do not visualise an increase in the present range of coloured lamps as the cheapest way of obtaining the diversity of colours that they have demonstrated. There are at present four saturated colour lamps and, with colour-change circuits, it is possible to produce almost any known colour; if, however, one is not prepared to spend the money on these special circuits, similar results could be obtained by extending the present range of coloured lamps. Such a development would still further complicate lamp manufacture and distribution.

I would agree with a previous speaker that, providing the fluorescent lamp has a good rendition, much can be achieved with contrasting colours in the decor. I would suggest that a De Luxe lamp of good colour rendering behind a pelmet will go halfway to meet the authors' plea, if the ceiling is painted a bluish hue and the wall is painted pink; the condition will not be entirely the same as, for example, a white ceiling with a blue lamp shining on it and a white wall with a reddish lamp, but it would go some way to meet the case. It would not be expensive because, although we have been told lumens are cheap, I suggest some of the distemper finishes are even less costly.

The last point comes from personal experience. I have lit my house entirely with fluorescent lamps and I have been very conscious that it is necessary to match the colour in one room to that in another. If we are going to have colour diversity in our homes, we may run into trouble. In our living room, we may feel very comfortable, and when we have been in our lounge for a little while we may again be comfortable, but when, unfortunately, we get up and move from one to the other, unless we pay particular attention to our schemes, they may be ruined by incongruity which will be obvious.

MR IMRIE-SMITH: I was particularly interested in Fig. 9 of the paper, in which we are given the colour tolerances of various surfaces such as beef-steaks, potato-crisps, etc. I note this chart has been extracted from the C.I.E., so do not know its

context. It does strike me as being very important, because, to my mind, everything on that chart can be explained by psychology; it is not art; it is not colour preference; it is pure common psychology, and it illustrates the kind of problem that the illuminating engineer is going to hit if he starts introducing coloured lighting in areas where people are used to plain illuminants. Colours are quite good when you are looking at a stage set, but my opinion is that we are already finding that the public are getting very suspicious of colour of displays in such places as grocery stores, butchers, clothing shops, etc. They have detected the red or other coloured light source and they do not trust appearances, so that introducing colours where some utilitarian judgment is involved can be a two-edged sword.

Returning to Fig. 9, we find a rather restrictive tolerance on the colour of tea. I do not think I need say that, as far as the British Isles are concerned, the colour of tea is one of the standards of life, and people are most critical, and you can very readily be in trouble if you start making colour changes. Next we find we have quite a wide tolerance in the case of beef-steaks and potato-crisps; we are not all in universal agreement as to the desirable degree of redness of our beef-steak, or of the cooking of potato crisps. There is quite a large tolerance one is willing to accept, but when we come to the results for butter, it is very interesting to see that they give the smallest tolerance of all. Since time immemorial, butter and cream are commodities which the mind has associated with freshness, and they are always critically examined to see they really are fresh. One is less inclined to allow tolerance on a commodity of this kind than on a thing like a biscuit which you know will keep for weeks.

Then we come to a very interesting illustration, and that is the large difference in tolerances between the colour of the hands and the colour of the face. Apparently we can accept quite a large colour change on our hands but we are very critical of our faces. This, I suggest, is again quite natural, in so far as we are used to seeing our hands; we see them all day long—sometimes they are not as clean as they might be—we do not spend all day staring at our faces, but if you look in a mirror to see your face, you observe it very critically. I dodge mirrors, of course, but the whole point is that if you want to see your face, you must deliberately look in a mirror, and you therefore become far more critical about colours than when you are looking at your hands, which you see all the time and take for granted. I think this illustration, Fig. 9, is a very important clue to the kind of psychological considerations that will lie behind questions of colour tolerance when tinted lights are employed in what might be termed semi-utilitarian areas.

DR. W. J. WELLWOOD FERGUSON: I would like to speak on the subject of colour as a layman, and purely from the artistic point of view. Mr. Waldram emphasises the importance of using complementary colours or anti-complementary colours in order to give emphasis. This device is used much in painting where "warm" colour may be made to stand out by a small area of "colder" colour in juxtaposition. Most paintings that have lived and are satisfactory to look at are those which do no depend upon a pure sense of colour, but in which the tone values are so good that even a monochromatic reproduction of the picture is satisfying.

While I am anxious to see a greater development of the use of colour in lighting, I would like to emphasise the necessity of basing the lighting scheme on correct tone values of "black and white" supplemented with colour. Colour should be used as a suggestion rather than as a basis.

MR. H. C. WESTON: The authors, at an early point in their paper, gave us a demonstration of the changes which took place with daylight and the few remarks I want to make are related to that. I am all in favour of diversity, but the point I would

like to make is that there is room, I think, for diversity in time as well as diversity in space, and I mentioned this point some few years ago in another context. In discussing the question of visual fatigue, I drew a distinction between visual fatigue and boredom, and I feel much of our artificial lighting to-day, good though it may be, lacks that vitality which is characteristic of daylight. I can well remember the time when it was impressed upon us that artificial lighting was advantageous because it was constant. It was not like fickle daylight. It did not keep on changing. But, providing you have got enough light for all times and purposes, surely fluctuation is an advantage; it gives life to the lighting, and I may perhaps compare the situation presented by our artificial lighting with the slides which the authors showed. Each of these was a "still" or, so to say, a cross sectional view in time; if we had to look at any one of them constantly, I think we would become bored and I feel there is great opportunity for us in the future in arranging for diversity of lighting in time. We can do that easily, of course, in the home, by having various sources; the time-honoured centre light, for example, and the floor standards and so on, and we can get up, from time to time, and switch one off and the other on, but I feel that we can go further than that and, perhaps, arrange some automatic control of the lighting quite apart from that of colour which the authors have demonstrated. We can surely develop brightness change too and arrange for a change in the position in which the shadows fall. Not long ago, I was very amused at one advertisement which suggested we should use indirect lighting and paint the shadows on the wall. I do not like to see my shadows always in the same place. We do not see them always in the same place in a room which is lighted by daylight because the sun does not stay still. Anyway, there I feel is a line of development for the future, and I would like the authors to tell us in their reply what they think about the possibility of arranging for diversity in time as well as diversity in space.

MR. J. F. PICKUP: In paragraph 4.3 the authors state that pelmet lighting has possibly been used in the worst way, i.e., for the lighting of curtains from above or below. It was also said that side lighting of curtains was more effective, but this was not brought out during the demonstrations. Such lighting is hardly practicable in most commercial or domestic interiors, but presumably one could use built-in lighting or narrow reflectors similar to those used for shop lighting. People in the theatre commonly light their curtains from above or below, with good effect. In domestic interiors, pelmets above windows are one of the few places apart from the garage or kitchen where fluorescent lighting can be employed without offence to the marital state. The pelmet should be deep enough to conceal the lamps from view, with the pelmet space 6 in. from the curtain, and the lamp about 2 in. behind the pelmet itself.

DR. J. W. STRANGE (in reply): Our reply to the discussion can be quite brief, because I think it was, if I may say so, a quite admirable discussion in the sense that it was throughout a constructive discussion of the points raised. For this reason it really calls for little except agreement on our part.

That, certainly, holds for much that Mr. Waldram said, which we found most interesting, and which we can support fully. Running through quite a number of the contributions to the discussion was a plea for a little caution in the use of colour, and with this we would agree. One can see the abuse of colour so often to-day. The use of saturated colours with contemporary decoration, is so successful if it is used in moderation, and so horrible if it is used without. If these saturated colours are used surrounded, say, by a dull or neutral colour, they achieve their aim, but if the colour is overdone, it can be most unpleasant. I might say that we were often warned of the horrible possibilities, and we are fully aware of them. Admittedly, in presenting the paper, far from blinding you in the accepted way with science, we have blinded you with girls, and in our use of coloured light, we did not use caution. In our

advice to you, as in the written paper, we recommend using colour with enterprise but also with some discretion. I fully agree with Mr. Weston, and also with Mr. Wellwood Ferguson. There are one or two points I would like to mention briefly.

I believe it was Mr. Waldram who referred to the problem of colour rendering, particularly when we had the contrast of food and the table covering. It is very true, and that runs throughout all this colour-rendering problem of food and clothing. We are dealing with a very complex matter. We depend partly on our memory of what food should look like, but also, partly on comparison with other things in the field of view. That indicates the technical difficulty of assessing colour rendering. The experiments we showed on the stage of taking out some portion of the spectrum of the illuminant and finding at what point this is noticed, is the true way of doing it, rather than by the binocular matching process, which gives a more sensitive check of colour change but is really quite inapplicable to our everyday conditions. But I would not underestimate the complexity of this colour-rendering problem.

Mr. Imrie-Smith, in referring to Fig. 9, really put into words what that diagram shows. In other words, he assessed by psychological reasons what Mr. Sanders found by physical experiment. I might say that the bulk of Mr. Sanders's work appears in a thesis which has not yet been published, which he did under the general direction of Professor Wright, a very interesting piece of work.

I think Mr. Waldram's approach, and our approach to this general question of the design in the visual field is very similar in some ways to the approach of the photographer to his task. I realised that when we were preparing the slides, particularly in two groups of four slides Mr. Hewitt showed in the early part of the lecture. These were not simple slides to produce. The photographer had to light his scene specially to give in the photograph what we saw in the visual scene. This is far from a simple operation, and the last series of four, which happened to be taken in my own home, were certainly not done with simple apparatus. My memory of the photographer's approach is very similar to Mr. Waldram's approach. He referred to the preacher in the pulpit with a very slight illumination from one side: the photographer gets the same effect; very often, he will arrange a white surface underneath his subject to get some light reflected up. We, as lighting engineers, can learn quite a lot from the techniques and devices of the photographer.

Mr. Bellchambers was worried whether we should have our families using make-up to suit our lighting. The only comfort I can give Mr. Bellchambers is that probably they will be using make-up sooner or later, whether we like it or not.

I can only say a very firm "No" to Mr. King in his request for a two-colour lamp. I shudder at the possibilities.

In conclusion, I really feel that the discussion was adequate in itself without a long reply from the authors. Mr. Hewitt may like to add one or two points.

MR. H. HEWITT (in reply): I should like briefly to make reference to the comments made by two of the speakers. Mr. Jackson described himself as a lamp maker pure and simple. I know other lamp manufacturers also, and I think they would all be deserving of our sympathy if they were asked to make a very wide range of colours of fluorescent tubes. Certainly, in our paper, we were not suggesting that. In fact, we were suggesting the alternative, that is, the use of colour-change circuits, which are being used on such a big scale to present this paper this morning.

With regard to Mr. Weston's plea for diversity in time, I think he is on our side. If I remember rightly, we did suggest there can be variation of illumination level from season to season, with the time of the day, from mood to mood, from event to event. We go further than that and ask for variation in colour also. Maybe that is looking rather far into the future, but I am glad that to some extent we have Mr. Weston on our side.

A Critical Analysis of Lighting Equipment and its Maintenance

By J. MORTIMER HAWKINS *(Member)* and C. J. VENESS *(Member)*

Summary

Although chiefly concerned with maintenance, this paper also draws attention to advantages and difficulties arising from the design and construction of lighting equipment. It gives typical examples of what is considered to be economical maintenance in factories, offices and stores. The experience derived from various light sources in relation to maintenance costs is discussed.

(1) Introduction

Although there now seems to be a noticeable swing back to tungsten lighting for store and speciality situations, this paper deals in the main with maintenance considerations of fluorescent lighting equipment because, at the moment, it predominates in industrial and commercial establishments. Also, because switch-start circuits exceed by far other methods of "striking," the main weight of comment is in this direction. Domestic premises are excluded, although many of the points mentioned can equally be applied to them.

Maintenance in a generic sense is as much a problem of economics as of technicalities, and in the field of lighting this is dramatically emphasised when comparing the simplicity of tungsten lighting with the much more complicated fluorescent lighting. In the old days a lamp failure usually cost the user the price of a new lamp, which he himself put in. To-day, however, he must call in a highly paid electrician and mate to determine whether the failure is due to the lamp itself, the starter switch, the choke, the condenser, the supply, or dirt in the lampholder.

The authors feel that too little thought has been given to this aspect; in fact they are convinced that far too much thought is given for to-day and far too little for to-morrow. It is true that we have heard manufacturers use the word "maintenance," but some tend to pronounce the word glibly, without due regard to what is economically maintainable. Contractors think that "maintainable" means "get-at-able"—accessibility so that labour costs are not unnecessarily high. Indeed, their opinion seems to have some support, even if one has to go outside this country to get it. Aspestrand of Norway said at the last meeting of the International Commission on Illumination in Zurich: "It is amazing that the lamp firms, having improved the light source by 10 per cent., should stand idly by while the fittings manufacturers supply fittings which steal three times 10 per cent."

No less amazement seems to be justified concerning the lack of action and practical interest by the lighting industry as a whole in regard to regular and effective cleaning, although it is true that in a report on industrial lighting given by the British Secretariat Committee to the Commission in Zurich two lines were devoted to the desirability of maintaining the recommended lighting conditions while installations were in service.

From Sweden comes a report on school and office lighting in which the following appears: "To the cleaning of luminaires . . . little attention is paid . . . especially for fluorescent fittings with glass sides it is impossible to get the ordinary cleaning staff to deal with these things."

Organised maintenance bristles with difficulties—nobody knows that better than

Mr. Hawkins is with Mortimer Gall & Co. Ltd., and Mr. Veness is with J. G. Sneath Ltd. The manuscript of this paper was first received on March 7, 1956. The paper was presented during the Society's summer meeting at Harrogate on May 9, 1956.

contractors—but it is hoped that by calling attention to some of these difficulties, the more enterprising manufacturers will be persuaded so to improve their designs and construction as to reduce the amount of time spent in placating users concerning the high maintenance costs—in which atmosphere, of course, it is difficult to persuade users to have even more maintenance.

Before one can analyse anything critically, its conditions of use must first be clearly stated and understood. In the case of lighting fittings, it seems to the authors that the following factors must condition all designs produced :—

(1) Ease of installation.
(2) Efficiency in terms of quality and quantity of light output according to the application—that is, purely functional, or decorative.
(3) Constructional details which will enable this initial efficiency to be easily and economically maintained in regard to :—
  (a) Electrical maintenance, including lamp performance.
  (b) Cleaning and re-lamping.

(2) Ease of Installation

(2.1) Mechanics of assembly—Instruction Sheets

If fittings must be delivered in parts, it is of vital importance to remember that costs of assembly are falling on the contractor, and therefore that all the parts must, in fact, be included in the initial delivery, and adequate instructions and diagrams sent either with the acknowledgment of order or with each fitting.

In this country much time is lost, not only in finding out how things assemble, but—even with well-known makes of fittings—rectifying inaccuracies of manufacture. Such things as holes which should tally but do not; stubborn knock-outs; spring clips which have been so painted over as not to function properly; suspension holes partly covered by chokes fixed in the wrong position; wiring trapped to earth during factory assembly. Instances of the latter point are not discovered until the fittings are ready to be put into service, and then, of course, the fault must be tracked down to one of anything up to 10 fittings.

The authors do not suggest that every consignment suffers from all of these defects, but in order to check their own experience, a questionnaire was sent to all branches of the Electrical Contractors' Association asking, among many questions: "What is your opinion of the mechanics of assembly?" Here are some of the answers :—

Hastings :	Generally too difficult.
West Yorkshire :	Should be assembled before delivery.
Birmingham :	Generally rather poor.
Gloucester :	Must be supplied wired up.
Northampton :	Could be a big improvement in assembly.
Newcastle :	A great deal still desired. Some of the leading manufacturers do not line up their bolts carefully.
Halifax :	Designers not maintenance-minded.
Wolverhampton :	Plenty of room for improvement.
Central Yorkshire :	Needs considerable improvement.
London :	Bits and pieces often missing. Site conditions not favourable for assembly.

A reasonable cross-section of the country, we suggest, indicating that we are not voicing merely personal complaints.

(2.2) Fixing centres

To those few manufacturers who produce fittings with infinitely variable fixing centres we tender the thanks of all contractors for meeting the representations they

have been making for some years. Unfortunately, much remains to be done, since in a survey of only four leading makers, we find that they market 4-ft. and 5-ft. fittings with no less than 22 different suspension centres, ranging from 17 11-16 in. to 57 in. How can a contractor position his outlet boxes correctly, and what happens when the user wishes to make a change?

(2.3) Captive screws

Installation labour costs could be reduced if a greater use were made of captive screws; the time taken in recovering dropped screws will be obvious. Screws should be put into fittings after enamelling, so that the slots in screw heads and the washers are not filled with paint.

An example of the benefit captive screws would confer is to be found in the popular "Seagull" fitting, where even with the products of good manufacturers the reflector is difficult to fix. Long-end screws are provided, and it is no easy task for the maintenance electrician, balancing on a step-ladder and supporting the reflector with one hand, to find the tapped hole. Why not captive screws over which the reflector could slip? Then by sliding sideways into a quarter-inch slot and clamping the assembly could be completed without fuss or bother.

(2.4) Concealed starter switches

Many ceiling type fluorescent fittings have their starter switches concealed by the end caps, and the maintenance electrician has no more than an even chance in the choice of ends when fault-locating. When he picks the wrong end, the consequent 60-second waste of time in mounting the step ladder and removing the blank end-cover amounts to no less than two working weeks for every 5,000 such cases. This in itself would seem to justify standardisation on an unobtrusive but visible starter switch, fitted through a hole in the end-cover, or in the side of the channel, but never under the lamp.

(2.5) Lamping

The maintenance electrician should be able to fit a fluorescent lamp from one position. Since, however, this position is often the top of a step ladder we would suggest that by inserting bayonet cap pins into the straight slots of a spring-loaded lampholder, sufficient movement could be obtained to slide the lamp into its working position. To prevent the lamp falling through failure of the spring-loaded holder, two simple toggle joint clips would suffice, and thus do away with the continued use of a bayonet-holder requiring a twisting action, designed over 50 years ago to suit the vertically suspended carbon lamp.

It is, however, realised that at this stage it may be difficult and complicated to change from one form of lamp cap to another, and that, even if introduced, this would further complicate matters for maintenance staffs. But let there be no doubt that those who have to maintain fluorescent lighting installations have very firm views—and with good reason—on the unimaginative approach which is self-evident in fluorescent lamp caps and their associated holders.

This unfortunate situation might be regarded as an object lesson in the value of manufacturers co-opting, in the initial stages of design, the experience of contractors, and not allowing themselves to be unduly influenced by overseas practice, or by what is most suitable from a production aspect.

(2.6) Location of control gear

Control gear fixed on the front tray assists the maintenance electrician if the whole assembly can be removed to ground level by the simple withdrawal of a disconnecting plug. With many fittings one has to detach the tray and balance the weighty control gear in one hand whilst disconnecting. Where control gear is mounted in the channel,

the task of reassembly after repair is often made more difficult by loose internal leads hanging down and becoming nipped between channel and tray. Clipping the leads efficiently, to prevent sagging when in the inverted position, should be standard factory practice; it is quite easy to see how this simple requirement is not visualised when the channel is the other way up on the bench during manufacture.

(3) Selecting Fittings According to the Application

When the installation and maintenance contractor is free to guide the user in his selection from the available range of lighting fittings, both functional and decorative, it is possible to choose first-class equipment which has both a high light output ratio and is economic in maintenance. Lamentably, those fittings which measure up to such searching requirements are too few, and even they lack standardisation of simple components—hence our recurring plea on behalf of installation and maintenance people.

One example will suffice to emphasise the importance of selection in regard to the particular application. The building concerned was of a commercial character, and a very considerable proportion of the ceiling was suspended 9 in. from the structural ceiling. Without consulting the electrical contractor, flush fittings were sold to the user by a manufacturer; the result was declared first class and highly satisfactory. It was only when attention was needed to the power factor condensers that it was discovered that these were mounted behind the reflectors, and that consequently the whole fitting had to be dismantled, with consequent damage to decorations and costs running into pounds, in order to replace a component costing a few shillings.

Representing this as no more than the kind of situation which does arise, the authors believe that the installation and maintenance contractor can and must bring to bear his particular knowledge of local circumstances before a sensible selection and application of fittings can be assured.

(4) Lamps and Other Equipment

(4.1) Fluorescent lamps

It is fair to say that the life of fluorescent lamps has been found in practice to be more reliable than that of the smaller tungsten lamps. The 5,000 hours quoted by manufacturers is being achieved with reasonable regularity, although the lumen maintenance curve seems to fall off more rapidly than that which is prepared under laboratory conditions.

In well-constructed factories with ample natural lighting, managements sometimes accuse the lamps of failing prematurely. Observant installers whose maintenance contracts keep them in close touch with installations agree that because the light blends with daylight, lamps are often left alight on bright sunny days. We know of the admirable devices which bring on artificial lighting when daylight is reduced below the level appropriate to the task, but such methods are not always the answer. Good maintenance advisers persuade managements to appoint reliable individuals to oversee these matters, thus ensuring efficient conversion of lamp cost into effective life.

Conversely, many lamps are still in use far longer than their expected life, and because their initial cost is high, users cannot easily be persuaded to replace them. Even a lightmeter will not convince some industrial users that a group of lamps should be replaced when their employees do not complain of insufficient light (always assuming that production has not fallen with a diminishing level of illumination). An inherent device which would cause lamps to fail when a minimum light output had been reached would be an effective help in achieving the planned maintenance factor.

There seems to be unnecessary complexity in regard to colour rendering, and a too insistent comparison with that obtained from tungsten lamps. When this situation

is coupled with the wide range of alternative lamp colours, it is understandable that users are confused and critical. One acceptable standard colour of lamp for general service would go a long way towards doing away with continuous and critical comments, particularly from the feminine element in factory and office. Furthermore, it would help the maintenance man.

Even if manufacturers consider our appeal for one standard colour general service lamp to be impracticable, we feel that the range of fluorescent lamps has become too wide, and suggest that it should be reduced. When a new lamp is introduced, if there exists a lamp with similar colour rendering properties, the earlier lamp should be discontinued in favour of the new and more efficient introduction. As an illustration of this point, it would seem to us that with the introduction of the "Natural" lamp, the "Daylight" lamp could have been discontinued.

We hear much critical comment about flimsy metallic strip fitted to instant-start lamps. The strip does not seem to stand up to very much cleaning, and where these lamps are held by spring clips, the strip can be irrevocably damaged by them. Is it not practical and economic, therefore, to standardise on a silicone coating for all lamps? Stocking problems for manufacturers, wholesalers, contractors and users would thereby be very much simplified.

(4.2) Starter switches

Whilst we agree that both thermal and glow starter switches must be available to replace those already in service, standardisation on one or the other type would, at this stage, seem to offer distinct advantages.

The contacts of glow switches have a habit of welding together, although serious trouble does not often result because users recognise the symptoms of failure and switch off. Certain trouble does, however, arise where lamps are switched in groups and switching off is not practicable. This may be a short-coming which manufacturers can overcome.

The new type of two-pin starter switch seems to be a helpful step in the direction of simplification; but in the opinion of the authors it has been introduced far too casually—in fact the existence of these new type switches has been realised only as a result of difficulties in the field, for if the spring contacts in the switch holder fail to make good connection, then the heater coil circuit is inoperative. This is not so, of course, with the four-pin starter switch, which has a solid connection between the heater coil points.

Contractors are quite unanimous in their views that :—

(i) Starters should never be mounted so that it is necessary to remove the lamp, or any other component, in order to get at them.

(ii) Starters should protrude sufficiently to enable an effective grip to be obtained; or alternatively a better design of canister should be produced to facilitate removal after a long period of installation. (See Fig. 1.)

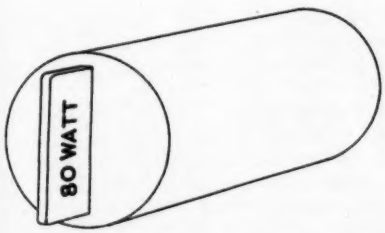


Fig. 1.

(iii) No starters should be arranged in a vertical position (contacts down), so that any volatile matter in the starter, or ambient condition in the air, can result in an accumulation of gummy substance in the starter switch holder, so making removal difficult if not impossible.

Regarding identification, we would welcome some reason from manufacturers why it is not possible to achieve standardisation in stating the function of the starter switch on the switch itself, and not merely to give a catalogue number on the box containing the switch. Boxes get lost, and not all electricians are familiar with related descriptions. It seems to the authors that a colour code might well solve most of the difficulties of identification; and if this trend, which has been announced whilst this paper has been in course of preparation, is to be successful, then standardisation of colours is obviously vital.

(4.3) Lampholders (B.C. and Bi-pin)

Contractors are unanimous in condemning bi-pin caps. The flimsy lamp pins are susceptible to damage when once out of the wrapper, and good contact is not so readily established as with bayonet caps, consequently a greater incidence of radio-interference occurs, particularly in fringe areas.

Will manufacturers consider standardising on bayonet caps for the complete range of lamps? This change would sweep away many installation and maintenance problems.

(4.4) Reflecting surfaces

Whilst stove-enamelled reflecting surfaces for fluorescent lamps are satisfactory for the clean atmospheres of offices and shops, in factories the relative ease with which good vitreous enamelled surfaces can be brought back to their original lustre eases the task of maintenance. We suggest that maintenance should have greater prominence when a lay-out is submitted to the purchaser.

It is not uncommon for an installer, who has subsequently to maintain an installation, to find his task made much more difficult because the initial order for reflectors has been obtained from the factory owner on price alone. The arguments used by those who put forward the right reflecting surface at a higher price become clear to the purchaser when it is too late.

Much difficulty is experienced in cleaning stove-enamelled reflecting surfaces in factories having dirty or fume laden atmospheres. After a relatively short period the surfaces become discoloured and require three or four times the labour just to clean them. A further drawback to stove-enamelled reflecting surfaces is that after a year or two in service, continual cleaning roughens the surface and seems thereby to accelerate the deposition of dirt. Where, however, the use of stove-enamelled reflecting surfaces is dictated by price, the coating should be one of the modern soap resisting, synthetic resin-based enamels which cure at a relatively high temperature, and have a degree of flexibility.

In general, those reflectors which permit the easy removal of reflecting surfaces to ground level for cleaning are to be recommended from the maintenance point of view, especially if the reflecting surfaces are removable without disturbing either lamp or control gear.

An earlier paper on maintenance by Robinson and Strange referred to the important self-cleaning effect of adequate ventilation. This is supported by the authors' experience. Slots which are provided primarily for upward lighting should be so positioned that they give the maximum benefit from the scavenging effect of convection currents of air passing over the reflecting and lamp surfaces. Where dust-proof covers are fitted the seal must be complete.

(4.5) Mounting and interchangeability of control gear

Control gear housed in any fitting should be easily accessible for fault-finding and, if necessary, replacement. Many designers overlook the heavy labour cost of dismantling a fitting when it is necessary to replace a component. This work has often to be accomplished at some height above floor level, and may necessitate stopping production.

Failure of P.F. capacitors after a few years is not uncommon, and we feel that an improvement in the technique of manufacture could prolong their life. Breakdown is not always due to a dielectric failure, but it is sometimes caused by deterioration of the lead-in wire insulation; the cure for this should be relatively simple. Many chokes to-day are impregnated to withstand high temperature operation, and since such impregnation does not increase the cost, it should be universally adopted to meet the high ambient temperatures often found in new installations.

The failure of radio interference suppressor capacitors is invariably due to a breakdown of dielectric. We feel that the chief cause is expansion and contraction in service, and that appropriate modifications in manufacture could prolong the life.

P.F. capacitors and chokes should have standardised physical dimensions, fixing centres and positions of terminals so that replacement does not require a maintenance man to take a multitude of spares.

Were this plea for standardisation implemented, it would eliminate the control "pack" which combines choke and P.F. capacitor (and sometimes starter as well) in one envelope. This is an expensive idea which has necessitated the scrapping of a whole pack for a relatively simple fault.

Since this country is still a long way from having a universal 240-volt supply (and even when it does, is it not certain that we shall still have end-of-network voltage drops?), tapped chokes are necessary to enable the maintenance man to take effective action on the spot.

In quiet surroundings the high-pitched hum of chokes continues to disturb. It has sometimes been necessary to make several changes before reducing this to a tolerable level, and the costs involved are resented, if not resisted, by the user, and as often as not have to be met by the contractor.

(4.6) Disconnecting plugs

It would be of benefit to installer and user if a disconnecting plug were standardised for all fittings. Such plugs would contribute to safety, for by the simple act of unplugging at the fitting, the whole unit is dead whilst being cleaned, inspected or repaired, and where, as is usually the case, fittings are switched in groups, disconnecting plugs are considered by the authors to be a necessity and not merely something to be desired.

(4.7) Tungsten filament lamps

In practice the claimed average life of lamps below 200 watts seems to be a somewhat arbitrary figure; were the 1,000 hours average claimed by manufacturers reliable, organised maintenance would perhaps be more worth while. Premature failure, often within 500 hours, necessitates interim calls between regular maintenance visits which increase overall costs and cause inconvenience, particularly to shop owners. The lamp life of sizes above 200 watts, and especially upwards of 500 watts, is more predictable.

The high initial cost of mirrored spotlamps has driven many users to replace them with close-fitting reflectors over standard tungsten lamps. Designers of these reflectors should pay more attention to ventilation and the scavenging effect of convection currents to reduce reflector cleaning and, at the same time, preclude the over-

heating of lamps. We suggest that a definite airway over the lamp be provided and, possibly, cooling fins on the top of the reflector which should be blackened to increase radiation. We are certain that much user criticism, following the premature failure of tungsten filament lamps enclosed or semi-enclosed in fittings or reflectors, should correctly be directed to the fittings designer who, with a lack of attention to this detail at the design stage, has failed to observe the excessive temperature rise in the lamp.

Factory maintenance includes such hazardous incidentals as hand lamps used by factory maintenance staffs. Assuming that such locations as boiler houses are properly provided with low voltage, there is little difficulty. In other areas, however, H.O. pattern handlamps use main voltage lamps, whose frequent replacement causes irritation to managements. So-called "Rough Service Lamps" of mains voltage do not withstand rough treatment. Can manufacturers produce something with the robustness of a carbon filament, having the light output and efficiency of its tungsten counterpart?

(5) Maintenance

(5.1) Cleaning maintenance for small to medium factories

In normally clean production areas, the frequency of cleaning reflecting surfaces and lamps would appear to vary between two and four times a year. Twice a year seems to satisfy managements whose factories need artificial lighting only during the period October to March, and in such cases cleaning takes place during September and January. In factories where the absence of adequate daylight calls for some measure of supplementary artificial lighting, the general practice seems to lean towards quarterly cleaning.

These comments are based on facts obtained from contractors in various parts of the country, and they refer to factories where cleaning *is* carried out, although it is a fact that organised cleaning maintenance is neglected in the majority of cases.

(5.2) Cleaning and re-lamping maintenance for small to medium sized premises

As indicated in Section 4, the group replacement of fluorescent lamps in production areas under this heading does not seem to have been widely adopted. This is often due to the varying usage of lamps, even over adjoining areas. Where, however, shift working is employed, a case can be made for group replacement. In these instances, the percentage failure basis is used initially to determine the period between re-lamping, because it takes account of improvements in lamp life and the switching cycle.

Cleaning is carried out more frequently than re-lamping, but when re-lamping falls due it is done at the same time as normal cleaning without unduly increasing the layout cost. An example of a scheme for a small production area is given below. Larger schemes, we find, are approximately multiples of this with plus variations to cover conditions which increase the labour element, for example:—

(1) Unusual height above the floor or cleaning platform.
(2) Obstructions below reflectors which call for plant in excess of that normally carried on a service van.
(3) Atmospheres leaving excessive deposits on reflecting surfaces which result in higher labour costs per reflector for cleaning.
(4) Inaccessibility for cleaning during normal working hours.

These and other similar variants are well known to maintenance contractors, who are able to assess their value. Within the compass of this paper, however, it is impossible to discuss these variables at length. We therefore content ourselves by quoting the simple example already referred to.

Example 1.—*A small factory*

Number of 5-ft. twin fluorescent reflectors	— 20
Height above floor level	— 20 ft.
Average initial level of illumination	— 15 lm/ft²
Reflectors accessible from downshop crane platform:	
Frequency of cleaning	— 4 times per annum
Frequency of re-lamping	— Once per annum
Approximate hours of use per annum (three shifts for six days per week)	— 4,200 hours
Cost per annum for cleaning and re-lamping service	— £47 15s.

This simple example does not cover the cost of interim calls to attend to isolated failures, nor the replacement of starter switches, because in this instance shift working reduces the switching cycle to once in 24 hours, with consequent benefit to starter switch and lamp life.

It may be of interest to note that the initial percentage failure test in this case went for 15 months, when the lamps had been alight for approximately 5,400 hours. The level of illumination had fallen to an average of 10 lm/ft² and it was therefore agreed to re-lamp annually.

Re-lamping, to obtain the best maintenance factor is carried out by changing lamps as follows (see Fig. 2):—

Those numbered 1 in January.
Those numbered 2 in April.
Those numbered 3 in July.
Those numbered 4 in October.

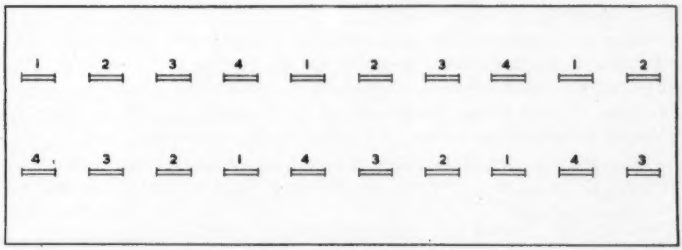


Fig. 2.

Cleaning *in situ* of these and other multi-lamp vitreous enamelled reflectors which are easily accessible is the normal method, a factor against removal being their weight and the liability to chipping of the vitreous enamelled surfaces.

With the large range of fluorescent lamps available, reliable records and maintenance men are necessary to maintain the correct colour rendering when lamps are replaced.

Example 2 is included because we consider it typical of the smaller establishment in a main thoroughfare which depends on service from a contractor, in preference to the employment of direct labour.

Example 2.—*Display windows of a small store*

Number of 150-watt tungsten lamps	— 30
Number of 80-watt fluorescent lamps (for background lighting above louvred ceiling)	— 16
Number of starter switches	— 16
Reflectors and lamps easily accessible:	
Frequency of cleaning	— monthly
Frequency of re-lamping:	
Tungsten	— quarterly
Fluorescent	— annually
Hours of use per annum	— 5,100 hours
Cost per annum for cleaning and re-lamping service	— £62

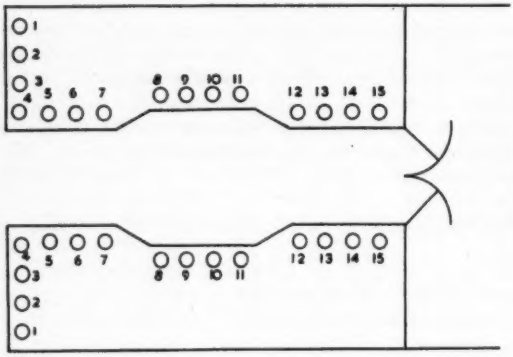


Fig. 3.

Tungsten lamps
Change
1, 4, 7, 10, 13 Jan., Apr., July, Oct.
2, 5, 8, 11, 14 Feb., May, Aug., Nov.
3, 6, 9, 12, 15 Mar., June, Sept., Dec.

Fluorescent lamps (16 x 5ft.)
Above louvred ceiling
Change 8 in Jan. and 8 in July
(alternate lamps)

It is interesting to note that with mirrored spotlamps, the price for this service would be increased by £94 per annum.

For comparison with this system of organised re-lamping, we now give two examples of the experience encountered in dealing with the problem of maintenance on an *ad hoc* basis—that is, as and when required.

Example 3.—*A small factory*

Number of single-lamp reflector fittings	— 35
Height above floor	— 9 ft. 6 in.
Hours of use	— Approximately 3,000 per annum
Number of service calls (1954)	— 22 (One fitting was visited three times and two others on two occasions each)
Total number of new lamps	— 20
Total number of new starters	— 7
Cleaning	— 3 times per annum
Average time from receipt of service call to attendance on site	— 52 minutes
Average time on job	— 35 minutes
Total cost	— £39 19s.

Example 4.—*A drawing office*

Number of twin-lamp reflector fittings	— 48
Number of single-lamp reflector fittings	— 10
Hours of use	— Approximately 2,000 per annum
Number of service calls (1954)	— 37 (One fitting required attention four times, two on three occasions and eight were attended to twice each)
Total number of new lamps	— 32
Total number of new starters	— 23
Total number of new capacitors	— 1
Total number of new holders	— 5
Cleaning	— 3 times per annum
Average time from receipt of service call to attendance on site	— 65 minutes
Average time on job	— 45 minutes
Total cost	— £72 14s.

It seems difficult to draw any conclusions from these four representative cases, because of such variants as :—

(i) Hours of usage and switching cycle.
(ii) Accessibility during normal working hours.
(iii) Distance from contractor's hub point.
(iv) Possible incidence of interim calls.
(v) Difficulties to be overcome as the result of bad initial planning.
(vi) Difficulties to be expected from badly designed equipment.

(6) Conclusions

The neglected field of cleaning and re-lamping maintenance does not reflect credit on those engaged in the lighting industry, and it provides a challenge to all of us who are so employed, to resolve the many difficulties which exist in fittings design, lay-out planning, selling, and the contractor's administrative and labour organisation so that he may provide this essential service effectively, economically and profitably.

Those responsible for the maintenance of lighting installations have to overcome problems arising from the partial or complete failure of isolated light sources occurring between planned maintenance visits; they are therefore vitally interested in the reliability and interchangeability of lighting equipment generally. Standardisation of components is long overdue.

The design and quality of lighting fittings, especially fluorescent fittings, has an important effect on maintenance costs, especially in these days of high labour rates. To overcome prevailing deficiencies, we suggest closer liaison with contractors through the Technical Committee of the Electrical Contractors' Association.

The selling of the idea of organised maintenance is a responsibility of the industry as a whole; and such associations as the Electric Lamp Manufacturers' Association might well consider making their advertisements more objective in this direction, so that contractors can implement such advice as the industry makes.

The group replacement of lamps, including fluorescent, cannot by any means be universally justified; but acceptance by the user of the principle that organised cleaning of fittings is no less necessary than the regular cleaning of floors would be progress in the right direction.

Discussion

DR. BALLIN: As a member of the manufacturing fraternity, I must express my regret that the authors have not seen fit to reintroduce in their presentation this afternoon some adornments which apparently were cut out of the paper. I am sure we would have thoroughly enjoyed ourselves, and it would have done us a lot of good.

It is most useful to have a contribution from the point of view of the contracting side at a meeting like this, even though we must appreciate that the contracting aspect cannot necessarily be the only one to be considered. If you remember some of the early slides, we saw a beautiful empty space which was then spoilt by the inconsiderate user putting in machinery: this characterises some of the problems with which we are faced. Apart from the considerations of the installation and maintenance, there are the interests of the user himself and the architects, who have their own ideas of what they want to do, and, in particular, the matter of economics which always comes in somewhere or other.

Many suggestions given in the written paper are entirely admirable, but the question arises whether, in terms of fitness for purpose, the refinements are really always necessary.

It is, for instance, stated to be most desirable that a fluorescent tube should be capable of being installed from one end only; in other words, some spring type of lamp-holder should be provided to make this job easier. This is very desirable indeed but considering that, in an ordinary installation, two or three years elapse before a lamp has to be replaced, the question must be asked, is this expenditure justified in all cases? In the case of starter-switches (if you must have this slightly obsolescent device at all) the life is five or six years, and therefore, even if it is a little more difficult to install or replace, it may still be cheaper to do that than to have an expensive safeguard which is recommended by the authors. There are, quite clearly, in all these points, conflictions of attitude and of requirements.

I would like to refer to the recommendation for standardisation of control gear. We have a long way to go before we get anywhere near standardisation between manufacturers, because even manufacturers themselves are unable to concentrate on one type of control gear, not because they do not want to do so, but because of the requirements of customers—those people who want a very slim type of control gear to go into the narrowest space. It is often the users, architects, shop-fitters, who have other points of view. The very important point of easy access for maintenance conflicts very strongly with the modern trend towards built-in lighting; if you want a nice, neat flush ceiling with everything behind it, there is likely to be some difficulty in getting at the gear, but good equipment will last a long time, so this does not have to be done very often.

I am in sympathy with the authors on standardisation of fluorescent tube colours. It was in response to a very strong demand from the user side that these additional colours were introduced. The variety of tubes available is a constant nuisance from the manufacturing and stocking point of view, but when a manufacturer decides to withdraw a certain colour because he has a better one, some customer will not have it, and so we have to go on making the old one. I do not agree with the authors that they could have one colour, say "daylight," because there are the categories of standard "high efficiency" and "de luxe" tubes, which are specially designed for other purposes. I think it would be possible to reduce the number to four or five and to obtain other effects by decoration—matters which were referred to this morning.

In the paper, there is a spirited attack on the failings of fittings manufacturers, and I am quite sure, in the course of this afternoon, we shall hear a good deal about

that. Some manufacturers may feel that some of the criticism cannot be directed against them and that, perhaps, the authors have been a little unfortunate in their choice of the manufacturers they are using. But, nevertheless, I think all of us will go home and read the paper again quietly and look at our range of fittings, and I am quite sure most of us will learn a good deal from it. But, again, there is the choice you have to make between refinements and costs. There is a very desirable feature in having easily changed fixing positions for lighting fittings, but unfortunately that adds to the cost of the fitting, and in so many cases a standard position is easier to achieve and can be indicated to the contractor in good time by means of a specification; but if you want that little extra and if you are prepared to pay for it, then it is available.

The main emphasis of the paper as given this afternoon was put on maintenance, and here we are in a field where a great deal of joint educational work by the industry as a whole is very badly needed. The manufacturers alone cannot do very much in this field because whenever maintenance means buying new lamps, they are accused of trying to sell more lamps; and I do hope, as the authors are so high up in the councils of the Electrical Contractors' Association, they will, on their part, preach the gospel and help to get the story over that maintenance is of the utmost importance, and that maintenance obviously also includes group replacement of lamps, which was very fully covered in a previous paper before the Society by Robinson and Strange.

The authors referred in their paper to some means of terminating the life of a tube at a certain time. I am not aware of any device which would do this. Therefore, we are left with the need to educate people to realise that it costs them more, after a certain time, to leave lamps in than to take them out, and I feel that contractors can make a greater contribution in this regard than can manufacturers.

I believe I am right in saying that, in the United States, the idea of group replacement only became really popular when contractors took up the idea of giving an all-in price for looking after lighting installations and found it to their own advantage to change the tubes at a certain time. That caught on and users realised there must be something in it; a little experiment on these lines would be a great help in this country.

I was a little disappointed that the examples given at the end were left somewhat inconclusive. We are given four examples of the cost of maintenance, but it is stressed by the authors that no conclusions can be drawn, and I do hope it will be possible at the end of the discussion for the authors to give us a little more indication or to work out for us a comparable case. I think it is most important to have facts and figures to prove that in contrast to the high cost of haphazard replacement of equipment, a planned campaign, possibly coupled with the proper cleaning of installations, saves money not only in terms of quality of light but in actual cash to the user.

MR. HOWARD LONG: I feel somewhat surprised that the authors have found all the troubles they have enumerated. If I had been asked to write out the requirements of design in lighting fittings, my specification would have been very similar to that given in the paper. I think the authors have covered the field very well. It is, however, of great advantage to the Society and to the industry generally that we should note the thoughts and experiences of the installers and users of lighting equipment and I think, in that respect, this paper has been a very valuable contribution to the transactions of the Society.

MR. A. H. OLSON: I am afraid I do not quite agree with the authors, particularly where they state that selling organised maintenance is the responsibility of the electrical

industry as a whole. I am of the opinion that as the contractor is in direct contact with the user, it is his function to endeavour to sell maintenance, particularly on new lighting installations.

The second point is the training of electricians on a contractor's staff on lighting equipment. With the advances and new developments of lighting techniques and equipment, a lot of time will be wasted on site if the electrician is unfamiliar with the equipment. A typical example of this was seen after the introduction of the quick start gear, when extra time on site could have been obviated if the necessity for earthing the installation and apparatus had been appreciated fully.

Manufacturers have been asked to issue more information and instructions with products. Whilst this is highly desirable, it is still essential for a close relationship to be maintained between the contractor's technical staff and the electrician on site.

I do feel if these two points were improved we would get increased sales for the contractor, higher efficiency in his staff and at the same time better lighting for the user, all factors that would benefit the electrical industry.

MR. C. HUGHES: This paper seems to indicate that what the contractor wants is a fitting that causes him no bother at all and, of course, if luxury equipment is wanted, it can be obtained from any reputable manufacturer of these things, but do not forget that quality has to be paid for; you cannot have refinements without increasing the cost. The fittings business seems to-day, judging by the advertisements which appear in the Press, to be developing into a very low price market. Even the London evening papers contain advertisements offering a fitting complete with tube for 50s. I suppose some people buy them, so one may think that as they provide remedial work for contractors the latter may be grateful, but it cannot be the right thing to do.

Regarding bi-pin caps, I would say that we do not like them; I do not think anybody likes them. Let me go back into history. When fluorescent lighting was developed in this country in 1937, we put a bayonet cap on each end of the 5-ft. 80-watt tube and it made a very nice job. Then in 1939 this country was otherwise occupied, all our "know-how" was sent over to America and they developed the smaller sizes, and in developing the 40-watt 4-ft. tube in particular, they produced the bi-pin cap. At the end of the war, when we were able to get into this market again, we had perforce to adopt the same cap, because this country lives very largely on exports and lamps exported to various countries have to go into fittings which the Americans put on the market; therefore we must have the bi-pin cap. If the authors would like lamps with bayonet caps, they can be made, but if we have got to make all sorts of variations from standard, somebody must pay for them and we come back all the time to the question of cost and price.

MR. S. ANDERSON: While we have heard many criticisms of manufacturers and their products, which doubtless are justified in some cases, little has been said relative to installation and maintenance contractors. I would like to ask what safeguards are being taken to ensure that their highly-paid electricians are equally highly skilled in installation and maintenance work—have they, in fact, sufficient knowledge of the equipment they undertake to install and maintain? I speak with some feeling because, regrettably, I have come across many instances where the manufacturer has been quite unjustifiably accused of supplying unsatisfactory equipment.

One example which comes to mind is that of a shop installation where fittings containing two fluorescent tubes were arranged for connection in the twin-tube type of circuit. The installation electrician, a man of some experience, when examining the gear trays in the fittings, saw something he apparently had not met before. He noticed that the capacitors were not connected across the mains terminals of the fittings; this he thought must be a mistake on the part of the manufacturer, so he reconnected

the capacitors in the way he thought correct, finished the job and switched on. The installation seemed entirely satisfactory. Serious trouble started a week or two later when the user complained that the fittings were becoming very hot and were dripping a black compound. After investigation, the manufacturer found it most difficult to convince the user that there was nothing basically wrong with the fittings, the fault lying entirely with the electrician who had altered the connections.

Another case was where fluorescent fittings had been supplied, with the correct thermal-type starter, for a D.C. supply. Unfortunately, another installation, for A.C. supply, was in progress at the time and the contractor used the thermal starters on the A.C. job. When the D.C. job came to be completed, he used ordinary glow-type starters from his store! Of course, the fittings would not light up and the contractor blamed the unwitting manufacturer!

I cite these two cases to show that the faults are not all on the manufacturers' side and to emphasise to the contracting industry the necessity for ensuring that their men do know their job when dealing with fluorescent and other discharge lighting fittings. The old saying, "There are tricks in all trades," was applicable to fluorescent lighting when it was first introduced. But fluorescent lighting has now been with us over ten years and there is no excuse for the electrician not knowing his job. Manufacturers do their best to send full information about their equipment, but it is beyond their capacity to ensure that this arrives on site with the fitting.

It would rather appear from the paper that lighting fittings should be designed primarily for easy maintenance. I feel with the authors that this is important, but the primary function of a lighting fitting is to control and distribute light from the bare lamp to the best advantage. Maintenance is a good second, but this, surely, is the first requirement.

Attention has been drawn to the effect of dirt and its bearing on the design of lighting fittings. I would suggest that this can best be tackled at the root. Much more can be done, particularly in new buildings, towards excluding dirt which, of course, adversely affects not only the lighting fittings. In the long run, it would seem more economical to adopt measures to prevent dirt getting into a building or to extract it at its source, if this is inside.

The point regarding starter position indication is a sound one, but I suggest, where the starters are hidden, it would not be difficult during erection to adopt the practice of always having the starter end of each fitting nearest the door; once the maintenance electrician knows that, he will waste no more time on this score.

MR. R. V. MILLS: In the written paper, the authors have quite rightly drawn attention to the fact that poorly designed fittings can result in increased maintenance costs. This fact, I would assure them, is well appreciated by manufacturers.

During our investigations into the problem of maintenance, we have also found another result of using fittings which are difficult to maintain, that of a reduction in lamp life performance. Five batches of lamps were taken from the same period of manufacture and put into five different installations. The installations were chosen to have closely similar conditions of burning and to have similar maintenance schedules. Batch one was put on laboratory life tests and there were no failures at 4,000 hours. Batches two, three and four were in installations with fairly well-designed fittings, and the lamp survival was only a few per cent. below that of the rack tests. Batch five gave a very poor survival curve and, on investigation, we found that the fittings in this installation were very difficult to maintain. They were very poorly constructed, giving considerable contact trouble.

Some of the more recent developments have, I believe, overcome many of the authors' criticisms of fittings which were designed several years ago. We found, in investigating the performance of instant-start circuits, that the increased cost of this

type of starting gear has been well justified by the reduction in maintenance costs. The introduction of fixed BC lampholders would seem to satisfy the authors' plea for one hand lamp replacing. Reflecting coatings now being applied to the inside of tungsten, discharge and fluorescent lamps, will give much better maintenance under dirty conditions, but I hope that this will not lead to neglect.

It is doubtful whether the user would be satisfied with a smaller number of fluorescent lamp colours. Manufacturers with the collaboration of users have made a real contribution in selecting from the many hundreds of lamp colours that could be made, two main high-efficiency types for general industrial and commercial lighting and three de luxe colours.

MR. J. K. FRISBY: I have read this paper with very great interest, listened to its most polished presentation almost with fascination and feel that the authors are to be congratulated on preparing a paper which is guaranteed to cause at the least a lively discussion—if not argument.

As a lighting engineer with some experience of the planning of lighting installations and also of the design of equipment, I quite naturally found myself at variance with the authors on certain sections of the paper. At the same time, it is rather refreshing to be able to disagree wholeheartedly with sections of a paper and yet to appreciate that it has a very considerable merit and is a worthwhile contribution to design and development.

The criticisms in the paper were mainly aimed, I think, at components such as starter switches. Manufacturers have done a lot to make starter switches unnecessary, if not obsolete, and I think they are entitled to expect that the electrical contractors will back them up in trying to popularise the slightly more expensive, but far less troublesome, instant-start circuits. Mr. Mills has just mentioned fixed lampholders. With this type of holder it is quite possible for an electrician to go around and relamp a whole installation using only one hand from one position at each fitting.

In regard to the maintenance of control gear, I believe the majority of manufacturers now have some means whereby the gear can be removed from the fittings on a chassis and replaced with a service unit. This greatly simplifies testing and repairs to circuits.

One other point—the question of fixing centres; I wonder if this is really as important as it is made out to be. Surely, lighting installations are not wired up complete before the electrical contractor or the user has any idea of the type or make of fittings that he is going to install. Generally speaking, I would say that the criticisms contained in this paper would have been very much more difficult to answer five years ago. I am wondering if, at the present time when progressive designers have dealt with so many of the points raised, such a critical paper can be fully justified.

MR. G. E. KEMP: I think I will join with the authors in growling at the manufacturers. I am in charge of a number of showrooms and, as a matter of policy, I must purchase among different manufacturers rather than from a particular manufacturer, and the result of that policy is that there is an awful lot of maintenance. One gets repeated examples of control units that drip electrolyte onto the diffuser, or even through the open base onto the carpet—I will not say onto some of my customers' heads as they walk underneath. I have not actually had that experience, but I am expecting it any day.

I am still amazed that manufacturers make the open type fittings with the closed glass or plastic diffuser, which is nothing but a trap for flies and moths and literally needs cleaning once a week, and even then a couple of days after it is cleaned in the summer time it is again a disreputable looking job. It is quite an expensive type to make and buy and expensive to maintain.

We used to consider, in the old days, that electrical manufacturers employed

draughtsmen from gas undertakings: frankly, I still think some of them do, and I join with the authors about assembling fittings on the manufacturer's bench in the opposite way in which we have to erect them; as a result, the wires are trapped in the metal casing and are often punctured.

We employ about 50 electricians in my undertaking and do an awful lot of service work. We try, as do the authors, to get the service work done within a few minutes of receiving a complaint, but I am rather surprised that they are able to do the job so very rapidly. They seem to take about an hour and a half to receive the complaint and actually cure it. I do not think I can quite beat that, but we do send the first man available to do the job. It is an awful job instructing 50 electricians, many of them newcomers to the contracting side of the industry, in the design of fluorescent lighting fittings and control gear, and I would ask manufacturers for a bit more standardisation and certainly more information on the control gear itself, as to what is its purpose. Some of these youngsters cannot recognise them on sight.

A number of the higher priced lighting fittings, the sort of job we like to specify, do not operate satisfactorily on low voltages. In my area, and, I think in quite a number of other areas in the country, we still have a nominal 200 volts supply which will be with us for many years. I hesitate to say this since I am a power supply engineer, but we know that at certain times of the day the 200 volts nominal supply legitimately approaches 180 volts and at the end of the consumer's wiring this may even approach 170 volts, and some of the best lighting fittings in the world will not strike at these voltages, yet a number of the cheaper manufacturers have managed to overcome this problem and I would ask manufacturers to consider this if they are dealing with 200 volts enquiries. It is no use having perfectly made fittings if the lamps simply flash on and off all through the day.

I disagree with the authors on their contention that 1,000 hours' life is not to be expected from tungsten lamps. We maintain not only factory and shop, but also street lighting, which operates under some of the most arduous conditions. We have varying voltages, after midnight the voltage naturally is at the maximum and drops fairly low during the day; in addition, there is vibration on traction standards and tall mandatory signs and we do find that tungsten lamps of ratings from 25 watts up to 100 watts, and as the authors say, the larger ones as well, have quite a good life. We do not expect lamps to fail before about 800 hours and we find that the majority of them will last the 1,000 hours of reputed life and a fair proportion even exceed it.

Rather off the general run of the paper, but just to complete the story—spot-lighting fittings: the authors mention arrangements for scavenging dust from inside fittings and from the lamps themselves. It is all very well, but please do not forget that these fittings are often mounted under the soffit of the ceiling, the dust must go somewhere and it makes an awfully dirty mark on the ceiling. This type of fitting, particularly the large spotlight fitting, will hold a great deal of dust on its top surface and I wonder if we might not arrange a peaked top on the lighting fittings so that dust drops off rather than rests on the top from where it is carried upwards by convection currents.

MR. R. A. MARRYAT: I feel that the authors and the committee should be congratulated on the production of this paper, which challenges both manufacturers and contractors to provide better service to their customers. Fittings are available which meet the majority of the criticisms contained in the paper but, of course, they do cost rather more. In the first example of cost of maintenance given by the authors you will see that maintenance may cost £2 10s. per annum or thereabouts for one fluorescent fitting. If, by better design, we can save only 25 per cent. of that £2 10s. it would justify a capital investment of £5 extra per fitting, if we take capital to be worth 12½ per cent. per annum. Careful study of these figures shows that it is well

worth while getting the very best fittings, and provides ammunition to tell our customers why they should pay more for their fittings and why they should have them properly maintained. I hope that contractors will take up this matter and press it home very hard indeed.

MR. G. F. BEDFORD: Speaking as a contractor, I can do little more than support nearly all the main points raised by the authors, but there are one or two on which I should be very glad of a little more information.

With regard to the installations described in the paper for which maintenance costs are given, it is probably inevitable that these are relatively small in size, as in large installations a customer almost certainly has his own maintenance staff and is the only man who knows anything about his maintenance costs. If if were possible to obtain the experience of firms such as the large car manufacturers or I.C.I., who must have experience going over many years, meticulously costed, it would be of very great interest to know to what extent such firms have adopted the practice of group maintenance, and if such information can be obtained I think it would form a very useful subsidiary to this paper.

There are two questions I should like to ask: In the type of group maintenance job described, in two of which a proportion of the fittings are relamped at regular intervals, how do you get such a scheme into its stride? The first time you do it, you are presumably throwing out 25 per cent. of your lamps which have only done 25 per cent. of their life. Do you do a sort of general post with these lamps and try and fit them in somewhere else? And that brings me to the other point, which is—in any case, what do you do with the tubes after removing them? You do a group maintenance job and pull down a lot of tubes, of which 90 per cent. are still working. If a manufacturer comes from north of the Tweed, you probably leave them with him. Otherwise, do you try to explain to him with the aid of manufacturers' figures that he is losing money by retaining those tubes and take them back to your own place and use them in your own stores?

THE AUTHORS (in reply): It is true to say that when we wrote this paper, we not only knew we were being provocative but intended to be so, because, after all, to write platitudes gets one nowhere.

The chairman rightly said that lighting installations, when finished, are merely the end of the beginning and, frankly, we could not agree more. The points we have made in the paper show the beginning of things for those of us who are in the maintenance field. The reason we require better components is not, as Mr. Hughes said, to give us the contractors' paradise, which he so delightfully outlined, but so that we can do our job efficiently and at a reasonable cost.

Dr. Ballin first gave us a "pat on the back" and then proceeded to tear the paper to pieces. He said he was sorry that things had been blue-pencilled from the script and so were we, because we feel that at a conference our sessions should be good-natured and light-hearted.

He mentioned economics as being the deciding factor; of course they are, and the thing we are always up against in the maintenance field is ever-increasing labour costs. Hence our plea throughout this paper for standardisation and ease of installation. Ease of installation not so much from a new installation point of view, but for the occasions when we are called upon to replace equipment. He said you should know what fittings you are going to use when the installation is designed and you should arrange your outlet boxes accordingly. We think we are in agreement on that. What we are concerned about is the occasion when the user decides to alter

his installation and then we really are in difficulties, with a number of new fittings which simply will not join up with the outlet in the roof, the ceiling, or the conduit system, or whatever it is.

The standardisation of control gear and customer requirements—we cannot quite agree with Dr. Ballin on that. A later speaker mentioned customer requirements. We think we are reasonable people; we are not asking for standardisation for anything which would spoil its utilisation. What we are asking for is standardisation of those components which can easily be standardised.

There was a pious hope expressed by Dr. Ballin that fitting control gear behind a modern acoustic or similar ceiling will not give trouble, but we, the authors, are agreed that it does. We were accused by Dr. Ballin of using the wrong manufacturers; we think that our powers of discrimination are such that we use the right ones whenever possible, but again it is a question of economics; we cannot always use the manufacturer we would like to, but if we can sell the right article for the right job, economic maintenance follows. Mr. Marryat also mentioned this salient point.

We were rather pleased with the sting in the tail of Dr. Ballin's remarks. He said contractors and not manufacturers should spread the gospel of maintenance and group replacement. However, we do not entirely agree on this. We feel it should be a concerted effort, as mentioned in our conclusions. Therefore, if the manufacturer can get his side of the maintenance story over to the user, the contractor can contribute his share with a suitable follow-up. We admit that contractors have failed in this direction in the past. Dr. Ballin did mention our conclusions and also our facts and figures. We do apologise to Dr. Ballin and others; we could have filled the whole paper with instances and illustrations of actual installations which are being maintained, but felt that we should limit our references to typical cases, at the same time emphasising the variants which have to be taken into consideration in preparing new maintenance schemes.

Mr. Howard Long was surprised that we found so many complaints about the design of lighting equipment. Our "complaints," however, are not really complaints; they are suggestions as to the directions in which we feel manufacturers could help us with a measure of standardisation, and thus give us equipment which it is possible to maintain economically. Contractors are only too well aware of the ever-increasing labour costs; not only the rate the electrician gets per hour has to be considered, but also holidays with pay, public holidays, forms of insurance, sickness benefits, etc., and these costs are getting so very high in total that any form of standardisation by the manufacturers will ease our task and keep costs within reason.

Mr. Olson came down on the side of the manufacturers. He mentioned that selling organised maintenance is the duty of the contractor and of the industry in general. We do not agree with this; we feel we have work to do and we admit contractors are not doing all they should. Let us be quite fair about it, we have a joint job to do, and if the manufacturers do their share, contractors would be encouraged to do theirs. We think both parties are lacking in this and should admit it.

Training personnel for fluorescent fault location is a very important point; we know it is one of those things Mr. Olson has been stressing for quite a number of years, and he is absolutely right. It was also referred to later in the discussion by another speaker. We agree that only those who have had the necessary specialised training should be sent out on maintenance and fault location of fluorescent lighting units and that these maintenance men should be brought up to date with new developments as they occur.

It was mentioned by Mr. Anderson, who spoke from the manufacturers' point of view, that the occasion does occur when the contractor is at fault; he is provided with an extremely good fitting, but uses an incompetent electrician without adequate supervision. In these days of full employment all contractors are faced with this sort

of person, who requires extremely careful supervision. In our experience as contractors, the job you get is as good as the supervision you give it and no better. Therefore, we would say that supervision was lacking on the job to which Mr. Anderson refers and he has our sympathy, because we know of instances ourselves where men without the necessary skill have caused faults in otherwise excellent equipment.

Mr. Olson said contractors sitting in their head offices and not giving the men on the job adequate details are to blame for a lot of the troubles. We have also had a very glowing picture of a contractors' paradise conjured up by Mr. Hughes. We cannot answer for other contractors, but can assure Mr. Olson that contractors who are worthy of the name do see that adequate supervision is given at the installation stage.

Mr. Mills referred to poorly designed fittings increasing maintenance costs. He also showed a very interesting slide which we were unable to understand completely, which demonstrated the laboratory straight line of no tube failures and no diminution of light as Batch 1. Less favourable results were obtained with Batches 2, 3, 4 and 5 on actual installations. These results support our contention.

We agree that contractors have their part to play in selling the instant-start idea, It will be a happy position for us when the two prices can be brought into line so that it is unnecessary to explain why the difference in price should exist between switch and instant-start gear. Mr. Mills gave a spirited defence of the design items and we are completely in agreement with him: of course, we know there are fittings on the market which are perfect in every way but, unfortunately, there are too many of the other variety. Our aim is to focus attention on the latter.

Mr. Frisby said the paper would cause discussion; we hope it will, and we hope in will also cause no small amount of criticism, as we welcome criticism. He disagreed with some sections of the paper and agreed with others. We can only tell Mr. Frisby that we, the authors, are similarly employed in that each of us designs and maintains installations, but even we do not agree on all points, although we do so in the main.

Incidentally, we would like Mr. Frisby to show us how his electrician wanders round a whole factory and replaces all the lamps with one hand in his pocket—this is a feat we still have to see and are bold enough to say is impossible to-day.

Are standardised fixing centres necessary? Yes, of course they are—it is when replacement is undertaken that we require standardised fixings.

Mr. Kemp, as a power supply engineer, came very much in our direction; thank you, Mr. Kemp, we needed a little support! We were amused by the picture he drew of electrolyte dripping onto the carpet. He added to our criticisms on design of fittings one or two of his own—plastic fittings, and so on, and especially wiring being trapped. He mentioned 200 volts supply and he has our sympathy; we quite agree that the manufacturers should make good the deficiencies of supply voltage, and if the supply authority cannot keep its volts above 170 manufacturers should do something about it!

Incidentally, Mr. Kemp said that he did not agree with us on the life of smaller tungsten lamps. However, we do maintain our contention on this point. He was referring to street lighting, where the ambient temperature is low, and we were referring to shop lighting where it is high, and we did suggest modifications to reflectors where used with standard tungsten lamps. He mentioned the question of dust rising and causing black marks on ceilings; this was not our point, however. The paper makes reference to lamps put into shop windows and recessed into the ceiling. We entirely agree with Mr. Kemp's point that there is nothing worse than seeing black spots on the ceiling.

Mr. Marryat is President of the Electrical Contractors' Association and he has made the journey up here to support us; we are delighted he could come along because his time is extremely full this year. He agreed that fittings are available if we pay a

higher price, and he stressed the advantage of selling better fittings where the cost is less for maintenance; but, as he will know, it is not always easy to do that because sometimes two or three people are invited to quote for the same order. Good contractors have difficulty in selling against the competition of inferior manufacturers and, as we said in the paper, it is not until afterwards, when the installation proves expensive to maintain, that the owner realises we were telling the right story.

Mr. Bedford, speaking as a contractor, pointed out that the paper deals with small and medium sized installations, and asked for information on larger installations. We would refer him to an earlier paper by Robinson and Strange. He also asked how a maintenance scheme gets into its stride initially when early failures occur. It is the usual practice to save replacement lamps which have only been in use for a short time for the replacement of lamps which fail before the date on which they would normally be replaced.

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End of Volume

This issue (No. 10) completes Volume 21 of the Transactions, the index for which is enclosed with copies sent to I.E.S. members and subscribers.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members:—

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